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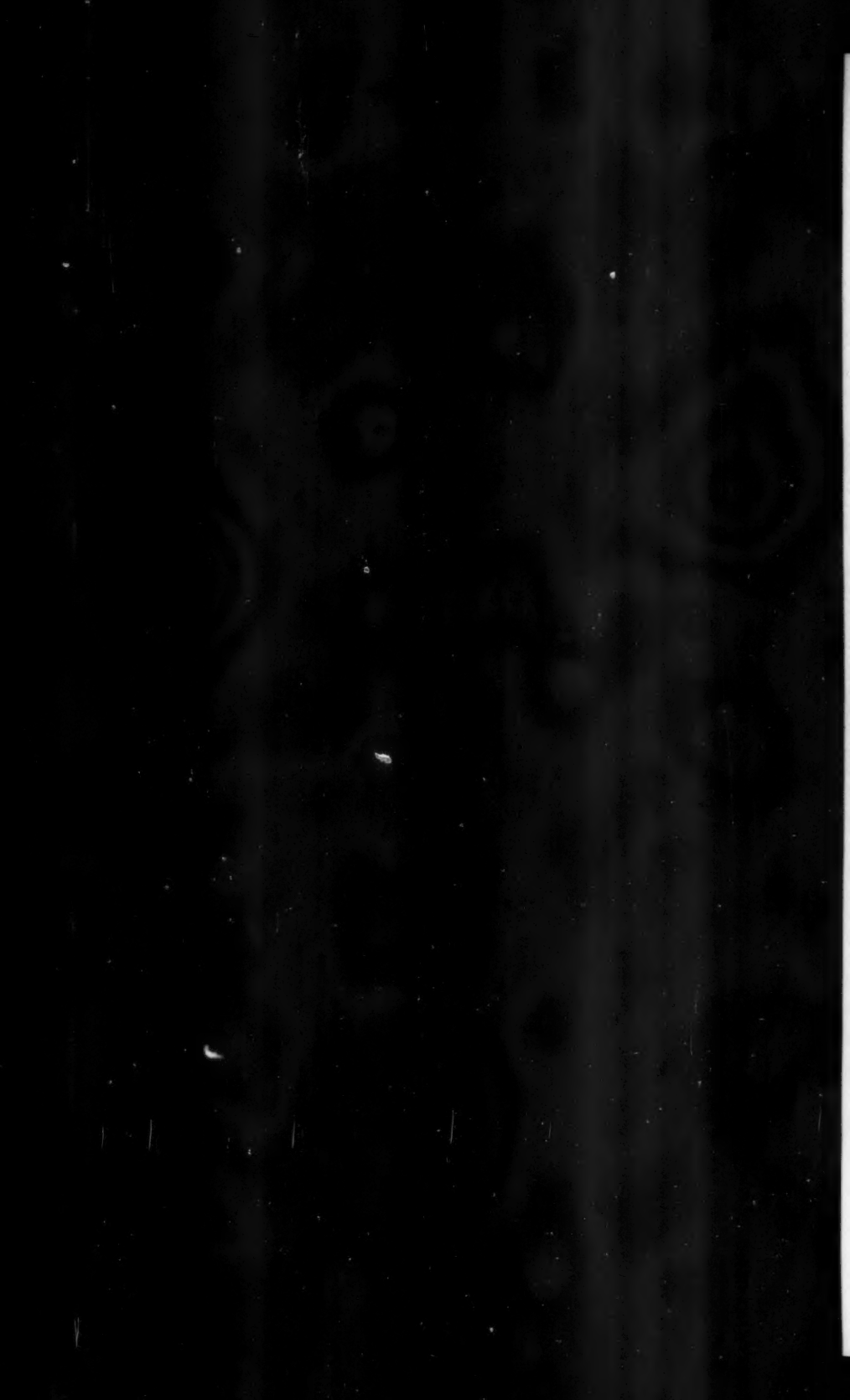


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXIX.—*Torsional Magnetostriction in Strong Transverse Fields and Allied Phenomena;* by C. BARUS.

1. IN 1885 Kirchhoff* published his remarkable research on the effect of stress on magnetization. This is the most comprehensive treatment which the problem has received and agrees in its applications with the deductions of Lorberg† and of Korteweg‡ for the analogous cases of electrostriction. It is well known that Maxwell's§ original stresses refer to a medium without structure. A subsequent generalization of von Helmholtz‖ makes the stresses in the electric or the magnetic field dependent on changes of density in the medium while Kirchhoff's stresses allow for a dependence both on bulk and on elongation. These stresses thus contain three constants, the first of which is either the susceptibility or the permeability of the medium (with the corresponding constants for dielectrics) according as in the original statement the magnetization or the magnetic induction is to be expressed in terms of the field. His second and third constants correspond to the bulk expansion and elongation in question. If the third constant is annulled, Kirchhoff's stresses coincide with those of von Helmholtz; if the two new constants are annulled Maxwell's stresses may be reduced. Other great authors¶ (J. J. Thomson, Hertz) have contributed to the subject in similar ways.

* Kirchhoff: Wied. Ann., xxiv, p. 52, 1885.
† Lorberg: Wied. Ann., xxi, p. 300, 1884.
‡ Korteweg: Wied. Ann., ix, p. 48, 1880.
§ Maxwell: Electricity; § 105, p. 146, vol. i; § 644, p. 255, et seq., vol. ii.
‖ Helmholtz: Wied. Ann., xiii, p. 400, 1881.
¶ The present meager account will suffice, since an excellent digest of the subject has been given in a paper by Nagaoka and E. Taylor Jones in Phil. Mag., (5), xli, p. 454, 1896.

Kirchhoff's theory has recently been examined in an elaborate experimental research due to Nagaoka and Honda,* with results showing an imperfect agreement with facts both for iron and for nickel. They not only include known reciprocal relations of stress and magnetization, but investigate new data particularly referring to changes of bulk. They find that Kirchhoff's new constants are complicated functions of strain, or that the expressions are applicable only to infinitely small strains.

As the phenomena, therefore, remain almost equally troublesome in terms of the constants of the theory, very little assistance has been gained from it; and in the entire absence of a better theory it is still permissible to look at magnetostriction from tentative points of view.

2. I have long been of the opinion that a statistical treatment of the subject, such as was suggested for viscosity by Maxwell, might have much in its favor as compared with the purely elastic treatment independent of the mechanism, sketched above. The reciprocal relations of stress and magnetization are, as it were, incidents in a much more varied phenomenon. Indeed the original explanation of the Wiedemann effect, as given by Wiedemann himself in terms of Weber's theory of revoluble molecular magnets (a theory which in Ewing's hands has been shown to include hysteresis) seems to have been too consistently ignored. The conception of a magnetic configuration which breaks down under stress but is restored when the stress has sufficiently vanished or been reversed seems to be a reasonable one, supposing the breakdown involves no chemical change, as it does for instance in tempering. In Maxwell's hypothesis *any deformation* due to molecular instability is a viscous deformation. Now when the breakdown is gradual in character, as it must be when depending on temporary local intensities in the distribution of heat motion, the deformation will be gradual as actually observed in the ordinary phenomena of viscosity. If however breakdown is instantaneous (kaleidoscopic as it were), due for instance to the molecular shake-up accompanying magnetization or its withdrawal, then viscosity is *instantaneously a minimum*, and the deformation correspondingly sudden or "static." There seems to be no theoretical gap here whatever, and I hope to show (more directly in the subsequent paper than in the present, which has an introductory character) that

* Nagaoka and Honda: Journ. of the College of Science, Tokyo, Japan, vol. ix, part iii, pp. 353–391, 1898.

with the interpretation I have ventured to give of Maxwell's conception of viscosity, the phenomena of magnetostriction become more closely akin, following the same course in all metals.

In discussing experiments like the present it is always desirable to devise a model of the simplest kind, which shall suggestively reproduce the phenomena in question as fully as possible. The model need not be looked upon as an actual occurrence. I will therefore insert a simple torsional mechanism around which the present experiments may be conveniently grouped. If we regard the rod to be twisted as a bundle of longitudinal fibers elastically bound together, then the effect of twisting is in the main an elongation of the fibers increasing from the axis to the circumference. Inasmuch as the external fibers are now helical in form, the stretch in question has a horizontal component acting along the circumference of any section, tending to restore the fiber to its original straight form. In a solid rod fibers inclined at 45° to the axis are subject to traction (with the accompanying compression at right angles thereto) only. Other fibers are both stressed and rotated. For the present purposes, however, a description in terms of the principle stresses is unnecessary.

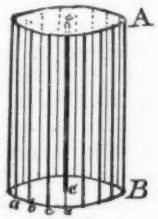


Fig. 1.

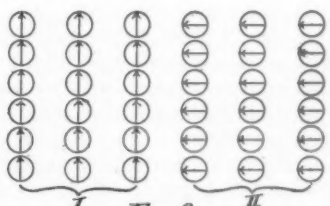


Fig. 2.

The case may be illustrated by the annexed model, in which the two parallel discs *A* and *B* are kept apart by the rod *C*, pivoted in a depression in each. Rubber fibers, *a*, *b*, *c*, ... symmetrically grouped, hold the two discs together and secure the rod *C* in place. If torque be applied to *B* relative to *A* the rotation is forcibly resisted.

The bands *a*, *b*, *c*, . . . correspond to lines of stress which bind the non-magnetic molecules, longitudinally. In the simplest case one would assume that in a direction along the lines of stress molecules are closer together than are the successive lines themselves in a direction at right angles thereto; in other words, the distance apart of lines of stress is large as compared with the distance apart of the molecules which conduct stress.

If this condition were dropped the model, though still available, would lack simplicity.

The effect of longitudinal magnetization as inferred from the axial setting of the revoluble magnets, is increased tension along the fibers and therefore a corresponding increase of the horizontal component in question. Rigidity is apparently increased under all conditions, as is inferred from the distributions given in figure 2, type I. My own measurements* in addition to the more recent experiments of Mr. H. Day,† in which strong fields were applied, show an invariable increment of rigidity, increasing towards a limit as the field strength increases, and greater as the diameter of the rod is smaller. All this would be suggested by the model, remembering that slip takes place on twisting when the obliquity‡ of the external fibers has reached a fixed quantity.

If the increment of rigidity due to longitudinal magnetization were to be associated with the Joule effect of magnetic elongation, one would expect a change of sign corresponding to the march of the latter in an increasing field. Rigidity however is a regularly increasing quantity and shows no change of sign of the kind in question; and this is just what the model indicates. Again for the case of nickel in which the Joule effect is at the outset opposite in sign to that of iron, the effect of longitudinal magnetization is nevertheless increased rigidity. An example of these results will be found below, §6. Figure 2, type I, is an extreme case. One may note that the poles of the magnets are closer together than the molecular centers, either longitudinally or laterally.

The effect of transverse magnetization, if the hypothesis of lines of stress relatively far apart be retained, is given as one extreme case by type II of figure 2. The molecular magnets tend to lie across the lines of stress and rigidity is therefore diminished. From the geometry of the figure, however, it appears that the poles of the molecular magnets now lie much farther apart than in case I. Hence the transverse effect should be a decrement of rigidity, under like circumstances of much smaller numerical magnitude than the increment of rigidity due to the longitudinal field. Thus transverse magnetization is adapted to test a variety of phenomena, and it seemed to me that an examination of these in very intense fields (much more intense than are available for longitudinal magnetization) might throw new light on the nature of magnetostriction.

The case of circular magnetization I had hoped to omit, as it was studied at considerable length by the original inves-

* Barus; this Jour., (3), vol. xxxiv, p. 175, 1887.
† Howard Day: this Jour., (3), vol. iii, p. 449, 1897.
‡ Barus: l. c., pp. 182–183.

tigators, and recently in the exhaustive researches of C. G. Knott,* and others. In Knott's experiments longitudinal and circular fields are superposed and the data are made tributary to Maxwell's† and Chrystal's‡ theories, in which the stresses of the Joule effect are sufficient to account for the torsional phenomena. Drude§ uses similar reasoning to compute Kirchhoff's third constant.

The immediate effect of circular magnetism is a decrease of the rigidity of the wire (iron, nickel) through which the current flows. The case therefore corresponds at once to type II, figure 2, or to lines of stress relatively far apart as compared with molecular distances.

The presence of an electric current, however, is accompanied with an accession of heat in the wire through which the current flows, and the diminution of viscosity resulting manifests itself in my apparatus and perhaps inevitably, as a diminution of rigidity. Hence in circular magnetization the heat effect is superimposed on the magnetic effect of the same sign and in thin wires it is difficult to separate them satisfactorily, if at all; for even if the wire carrying current is submerged in water there is still grave room for doubt, as will appear below.

For these and similar reasons I endeavored to investigate results with thin wires subjected to the strong transverse fields in the air gap of an electromagnet, for which conditions no data have as yet been forthcoming. In spite of the toil spent upon the work, however, my endeavors have not brought out sharp results, except in so far as they furnish a superior limit for the change of rigidity sought; and even this is a small and uncertain residuum raising a doubt as to whether rigidity is at all influenced by strong transverse fields.

Having completed this work I thus found myself under the necessity of taking up the question of the effect of circular magnetization on rigidity for comparison. The results were again such as to place doubt on the occurrence of such an effect.

3. *Method of Experiment.*—The apparatus used was virtually the same as that of my earlier experiments on the subject, except that the helix formerly surrounding the upper wire is replaced by the fissure-like air gap of the strong tubular electromagnet, *A*, figure 3. The upper of two identical soft iron wires, *ab* and *cd*, is placed in this gap to be strongly magnetized when the current flows through *A*. Any twist may be applied to the system *ab*, *cd*, by the torsion heads *D* and *E*,

* Knott: Trans. Roy. Soc. Edinb., (2), xxxvi, pp. 485–535, 1891.
† Maxwell: Electr. and Mag., ii, p. 109.
‡ Chrystal: Encyclop. Britanica, Art. Magnetism, p. 270.
§ Drude: Wied. Ann., lxiii, p. 9, 1897.

and both wires are thus subject to the same torque. The change of rigidity due to the transverse magnetization is observed by the mirror, *m*, reflecting a beam of sunlight upon a wall 5 meters distant. Hence 1^{cm} of deflection corresponds to about ·001 radian or ·057°. The mirror is provided with vanes, *vv*, dipping in an annular trough (not shown) to deaden vibration, as well as to carry a current from *E* to *v* for the circular fields. The rod, *e*, is suitably provided with a pin and slot arrangement, so that the wires may be kept under the definite tension of the weight, *W*.

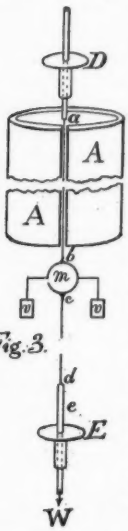


Fig. 3.

The core of the electromagnet, *A*, was of thick gas pipe about 37^{cm} long, 5·5^{cm} in diameter and ·3^{cm} thick, the longitudinal (vertical) air gap being about ·3^{cm} broad. It was wound from end to end with about 120 turns of wire. A fine vertical glass tube (not shown) about ·1^{cm} in bore was symmetrically secured within the gap running from end to end. Through this tube the wire, *ab*, was threaded to prevent adhesion to the sides of the jaws of the electromagnet. This occurrence in fact constitutes the chief difficulty in the experiments. Deflection of the wire toward either jaw is liable to be accompanied with spurious rotation. On the other hand too fine a tube interferes with the motion frictionally. In later experiments I discarded the glass tube in favor of a more carefully centered free wire.

During the tests with circular magnetization the lower wire carrying the current was submerged in a wide glass tube of flowing water.

The field *H*, within the air gap of the helix, measured ballistically with the aid of an earth inductor, had approximately the following c. g. s. values for different currents, *C*, in amperes. An attempt to secure sharp absolute values was needless.

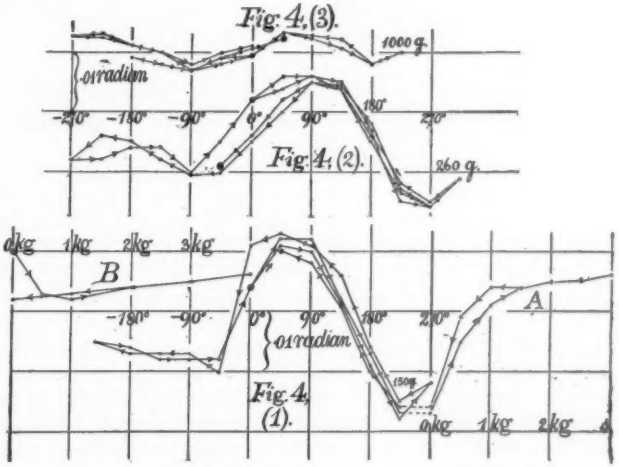
C=	1	2	3	4	5	6	7	8	9	10	11	12	13
H=	1200	2700	4300	5700	7150	8500	10000	11100	12000	12650	13200	13700	13950

Between 2 and 7 amperes in the helix the variation of *H* with *C* is very nearly linear. Below this it is slightly accelerated, above rapidly retarded. Since all fields were made from zero, the effect of hysteresis could be disregarded as was specially tested. The field here referred to is that within the air gap and found by differential experiments. If B_1 be the induction within the gap and B_2 the total induction, including the

* Barus: this Jour., (3), xxxiv, p. 176, 1887.

stray field outside of the gap, the galvanometer for a loop within the gap will respond to $B_1-(B_2-B_1)$. Two measurements were therefore made to compute B_1.

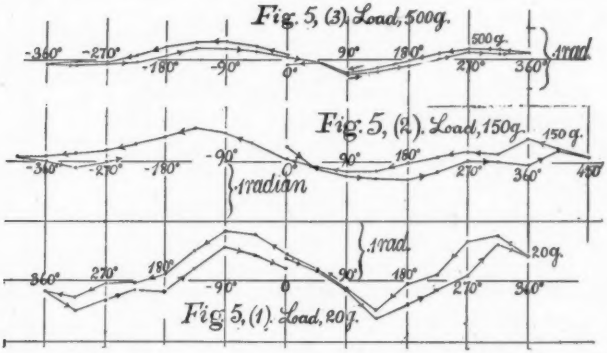
To prevent excessive heating currents between 5 and 6 amperes were usually employed, though these were not sufficient to saturate the core of the helix as the above data and the results below show. I may add that the ordinary effects of viscosity and slip are eliminated by the method of experiment, since the field was alternately made and broken several times.



The change δn of rigidity n, is at once given in terms of the deflections $\delta\theta$ of the mirror; for $\delta n/n=\delta\theta/\theta$, very nearly, if for the same section and length, θ is the twist simultaneously imparted to each wire. In fact the above method was devised to secure this convenience. If $\delta\theta/\theta$ is positive, i. e. if in the above apparatus the twist is imparted clockwise looking down the wire and the deflection due to magnetization is also clockwise from the same point of view, then the magnetic change of rigidity is an increment for upper or magnetized wire; and vice versa.

4. *Results.*—The chief difficulty encountered has already been suggested. If the wire is carefully straightened and adjusted in the middle line of the vertical air gap, the wire nevertheless becomes slightly sinuous or wavy when the magnetic field is excited. Different parts of the length of the wire are unequally attracted. If these parts lie across the field such attraction is accompanied by rotation and the observed

phenomenon, otherwise quite consistant throughout, is spurious. As an example I may give the series of results, figure 4 (1, 2, 3,) and figure 5 (1, 2, 3), for annealed iron wires ·044^{cm} and ·024^{cm} in diameter, respectively, and 41^{cm} long each. The twist, θ, imparted to either wire is given in degrees by the abscissas, positive or negative as specified. The ordinates show the deflections $\delta\theta$, in radians, obtained when the field is made, so that ·057 $\delta\theta/\theta = \delta n/n$ is the increment of rigidity.



The consecutive curves given correspond to successively increasing loads or vertical pulls on the system, as indicated. Observations were made in the cyclical way shown by the arrows. The same zero was retained throughout. In general for positive twists the return curve is positive relatively to the outgoing curve; for negative twists the return curve is negative relatively to the outgoing curve. Definite consideration will be given to this interesting result in my next paper so that the present reference will suffice for this and succeeding cases. The effect of loading (among many results of a similar kind) is specially shown in figure 4 at A, B, giving evidence even of sign reversal. The deflections are large for the thin wires as compared with the thicker wires (different scales are needed in the two cases). Special experiments showed that if a series is repeated the curves obtained, however irregular, are identical.

Notwithstanding the trustworthy character of the results obtained, I became convinced that the excessive effects produced by loading, and hence the whole phenomena, were somehow in error.

5. In the experiments of § 4, the magnetized wire was enclosed in the fine glass tube mentioned above. In the present experiments it is free (the tube being withdrawn) and visibly suspended in the air gap. The latter was adjusted after

each twist so that on making the field the transverse motion of the wire was the smallest possible. Rarely did I succeed in quite eliminating it. Moreover, to guard against errors of the

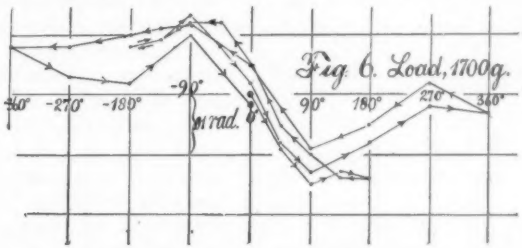


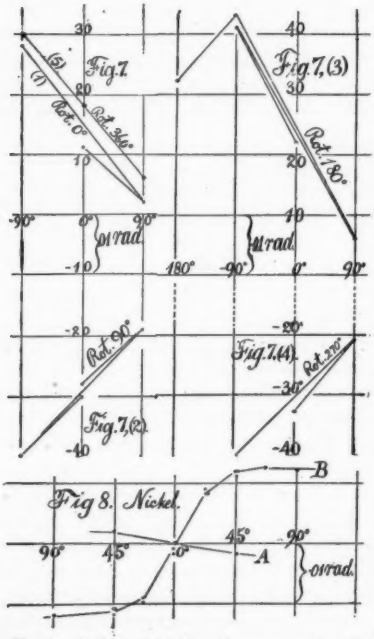
Fig. 6. Load, 1700 g.

preceding kind the wire was as heavily loaded as its section permitted, without passing the limits of elasticity. An example of the results so obtained is given in figure 6. The load suspended from the system of thin wires was about 1700 grams. The character of the observations has remained essentially the same as in the foregoing experiments, and the additional care bestowed has not reduced the complications.

To test the trustworthiness of these observations and to interpret them, I now *rotated both wires* of the system around their common axis and examined them for each 90° of displacement. The data are given in figure 7 (1–5), which is an example of many similar results with other wires. To facilitate the work the twists applied lay between +90° and −90°. The slopes of the lines obtained are about the same, but they are alternately positive and negative. In general when the deflection for no twist (fiducial zero) is positive, the slope is positive and vice versa: though neither this nor the alternation of sign seemed to be the invariable rule. One may note that the data for the initial (0°) and final (360°) positions agree very well as to slope.

The curves of figure 7 may be interpreted in two ways: either the wire is aeolotropically different in the four radial directions examined, which would indicate remarkably complex structure, or the wire is geometrically dissimilar, being either elliptical in section or not quite straight, or both. In both cases the curves obtained would be adventitious and the alterations observed easily explained: for if the wire is virtually ribbon-shaped with its plane oblique to the lines of magnetic force, the tendency of the ribbon will be to set "axially" when the field is made. For positions 180° apart the torques will be identical; for positions 90° apart they will vary as the sine and cosine, respectively of the obliquity, and will be numerically opposite in sign. If the obliquity be 45° or nearly so, the torques will be equal and opposite.

Assuming that in the given curves, figure 7, the obliquity of 45° has been reached, then from two consecutive positions of the wires relatively to the field (0° and 90°, 90° and 180°, etc.) the spurious effect may be eliminated. The slope so found, however, lies within the errors of hysteresis, set, and the errors of orientation and can not be considered more than an estimate. For the mean slope indicates an effect of but ·11° per 180° of twist, or 2^{cm} of deflection for a scale distance of over 5 meters. Hence even in the strongest transverse magnetic fields the persistent increment of rigidity remains small and is negligible in comparison with the spurious effects encountered.



6. After reaching this unexpected result it seemed necessary to verify it in other directions. In the first place the question occurred whether compatibly with figure 2, type I, the effect of longitudinal magnetization was an increment of rigidity in all metals. I therefore tested a nickel wire (length 41^{cm}, diam. $\cdot 048^{cm}$) in the longitudinal field by replacing the transverse helix *A*, figure 3, by an ordinary helix. An example of the uniform results is given by figure 8, *B*, and bears this out (current 4 amperes, load 150 grams, field 400 c.g.s. units).

On the same diagram will be found the apparent effect, *B*, of circular magnetization produced by a current of about 2 amperes passed through the wire, freely suspended in air. The obvious decrement of rigidity resulting seemed suspicious, however, inasmuch as the deflection on making the circuit was rapid and the return to zero on breaking, prolonged. This is nearly what would occur if the observed decrement of rigidity was due to heat alone.

7. Final experiments were therefore directed to a comparison of the effect of a circular field in iron and the effect of a similar field in brass, yielding it would appear a straightforward method of decision. In figure 9, I give a preliminary

example of the decrement of rigidity due to a current of one ampere in an iron wire suspended in air, compared with the effect when the wire is submerged in flowing water, other things being equal. It will be seen how relatively large the heat effect is, the decrements for the submerged wire being

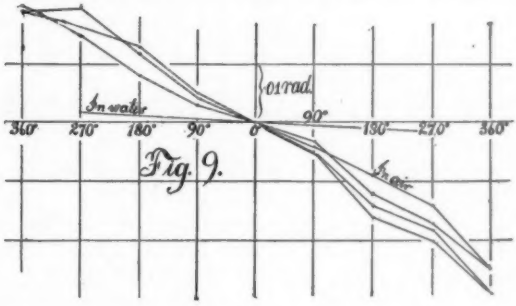


Fig. 9.

less than 1^{cm} at 5 meters of distance and 90° of twist lying within the errors of measurement. Apart from this the question is open whether even the submerged wire is not heated to an extent appreciable by the method of observation.

Hence in my concluding experiments I tested an iron and a brass wire of about the same dimensions, in the same apparatus and under like condition consecutively. Both were submerged in running water. The results for iron are given in figure 10, those for brass in figure 11. The wires were sufficiently thin

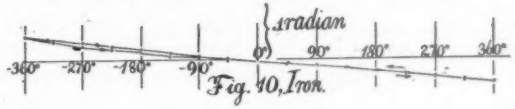
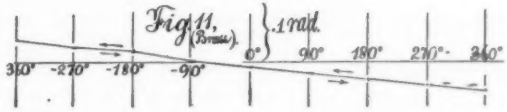


Fig. 10, Iron.



and the current strong enough to give large deflections (up to 50^{cm}). The current and diameter in brass (6 amp., ·020^{cm}) are smaller, in iron (7·5 amp., ·044^{cm}) larger. In both cases, however, there is a definite decrement of rigidity due to the circular field of about the same order, and in both cases so far as can be made out it is a mere heat effect.

I am obliged therefore to conclude, that in so far as these experiments have weight the effect of longitudinal magnetiza-

tion is an increment of rigidity in all paramagnetic metals; whereas the permanent effect of a transverse or a circular field is relatively inappreciable so far as rigidity is concerned. At least its certain detection would have to be left to researches of a higher order of refinement than was reached in the method pursued. This conclusion is at variance with much of the earlier work on the subject, but I do not see how the step for step march toward this result which the above simple experiments contain can be evaded.

Finally, the suggestions of the model (figures 1 and 2) are in keeping with the data found. Cf. § 2.

The quantity which I have here considered is the *permanent* effect of magnetization or rigidity, i. e., that which persists after making and breaking the field many times. Besides this there is a very striking temporary effect of marked relative value, in the interest of which the present experiments have largely been made. The relation of this temporary effect to viscosity will be considered in the paper soon to appear.

Brown University, Providence, R. I.

ART. XL. — *Notes on Tellurides from Colorado;* by CHARLES PALACHE.

1. *Sylvanite from Cripple Creek.*

THE presence of sylvanite among the telluride ores of Cripple Creek was first made known by the analysis of Pearce,* and the considerable silver content of the ores was credited by him, in large part at least, to that mineral. His analysis however was made on massive material, and the lack of crystallographic evidence of the presence of sylvanite, together with the failure of other investigators to find the mineral, led to some mistrust of his results and the silver content of the ores was doubtfully attributed to the common ore, calaverite, which was known to carry a small percentage of silver.

Of recent years, however, crystallized sylvanite appears to have been found in considerable amount in several of the Cripple Creek mines and it is the purpose of this paper to describe a series of sylvanite crystals which offer most satisfactory proof of the correctness of Pearce's original conclusion.

The crystals to be described were placed at the writer's disposal for examination by Professor Hobbs of the University of Wisconsin, to whom they had been presented by Mr. F. M. Woods of Victor, Colorado, the collector. The crystals were in two lots labelled respectively: "Sylvanite," Mabel M. Property, Beacon Hill, Victor; and "Calaverite," Victor, Col.

All proved to be alike sylvanite and consisted of isolated crystals and crystal fragments varying in size from 1^{mm} to 8^{mm} in greatest dimension. The color is pure silver-white and many of the fragments display the perfect cleavage parallel to the clinopinacoid which is characteristic of this mineral and serves well to distinguish it from the more common calaverite. The specific gravity, determined on three isolated crystals on the hydrostatic balance, was 8·161.

The dominant habit of the crystals is thin tabular parallel to *b*, 010, the edges of the tables being bounded by planes of the orthodome zone. The tables are frequently as thin as paper and the edge planes become too small to be measurable. A second well-marked habit is prismatic, determined by the pronounced development of the zone of the positive unit pyramid and orthodome, (111) and (101), and other pyramids of this zone. As will be seen from the figures, crystals of this habit are frequently rich in forms, some of which proved to be new to the mineral.

* Proc. Colo. Sci. Soc., 1894.

A skeletal development, well known on sylvanite from other localities, is common on these crystals; but it did not affect the character of the crystal planes which were in general brilliant, giving good reflections.

Measurements were made on the two-circle goniometer and the adjustment of the crystals was rendered very accurate by the use of the three pinacoids, nearly always all present.

The following twenty-nine forms were observed on the five crystals measured:

c, 001	*m*, 101	*r*, 111	*u*,* 723
a, 100	*n*, 201	*w*,* 343	Π, 341
b, 010	N, $\bar{2}01$	*s*, 121	*y*, 123
R, 120	*d*, 011	*o*, 131	*ρ*, $\bar{1}11$
e, 110	*v*,* 525	*q*, 141	*σ*, $\bar{1}21$
f, 210	*γ*, 212	*i*, 321	*J*, $\bar{3}21$
g, 310	*t*, 323	*j*,* 521	*κ*, $\bar{5}21$
			Y, $\bar{1}23$

In the following table are given the computed and measured angles for the four new forms. The forms *o*, 131, *q*, 141 and Π, 341 while not new, have not been observed since Miller's studies, and are here added, with their computed angles, in order to complete the tables of Goldschmidt by whom they were omitted as uncertain. The new form *u*, 723, is the most interesting, occurring in nearly all the measured crystals with good development and being apparently characteristic for this locality.

Letter.	Miller symbol.	Computed angle.		Average measured angle.		Variations.				Number of observations.	Quality of faces.
		ϕ	ρ	ϕ	ρ	ϕ		ρ			
						+	−	+	−		
v	525	57°·06′	39°·41′	57°·03′	39°·36′	12′	13′	7′	3′	5	fair
w	343	24·53	58·52	24·49	58·57	9	8	7′	6	2	poor
u	723	65·04	60·42	65·01	60·36	14	5	12	15	6	good
j	521	56·53	76·22	56·50	76·25					1	excel-
Π	341	24·44	78·36								lent.
o	131	11·39	73·50								
q	141	8·47	77·38								

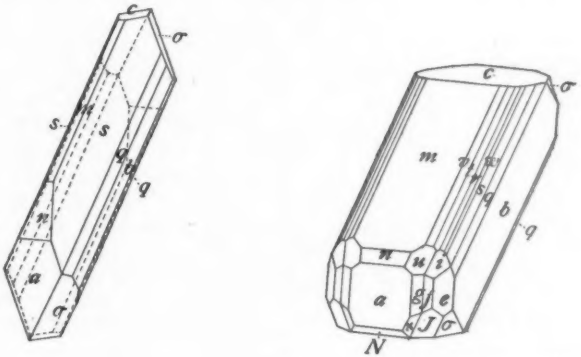
The figures illustrate the typical prismatic habit, as shown in various combinations of planes. In fig. 1 the pyramids are developed at the expense of orthodome and clinopinacoid; in fig. 2 the latter forms predominate, giving a tabular-prismatic character to the crystal. This zone of pyramids is generally

* Forms marked thus are new.

rich in forms as shown in fig. 2 and is sometimes deeply striated. It forms a satisfactory means of distinguishing the positive from the negative octants, which in its absence, owing to the nearness of the angle β to 90° in sylvanite, is not always easy to do.

Of the other pyramidal forms, σ, $\bar{1}21$, is the most common, being rarely absent and generally relatively large in size. The other pyramids, both positive and negative, and the prisms are

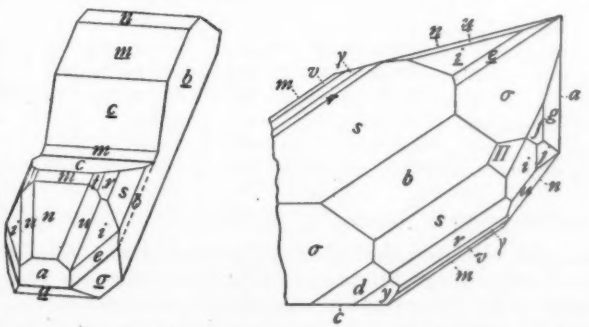
1 2



of very subordinate importance in defining the outlines of the crystals.

Two of the measured crystals were found to be twinned according to the common law for sylvanite, twinning plane the

3 4



orthodome, 101. Figs. 3 and 4 reproduce these twinned crystals in about the proportions of the originals. Fig. 3 will be seen to be a simple contact twin, in which, however, the two

individuals, in contact along the plane 101, are very unlike in development. The crystal figured in normal position is bounded by numerous positive pyramids and domes while the twinned individual is much larger and a much simpler combination. The reëntrant angle between the two basal planes with the intervening narrow portion of the twinning plane 101 made the twinned character of the crystal quite evident. In a subordinate development this mode of twinning is quite frequent, the twinned individual appearing as a narrow transverse ridge on the surface of the *m* plane of a larger simple crystal such as shown in fig. 2.

A less simple phase of the twinning is represented in fig. 4 in orthographic projection on 010, where apparently no plane boundary exists between the two individuals. The planes $\underline{n}$, $\underline{u}$, $\underline{i}$, and $\underline{e}$, constituting the upper part of that figure were only recognized as in twin position by the complex symbols which they yielded in the projection, whose study, in the light of the simple twin already observed, showed their true nature. It is possible, however, that this is a contact twin like No. 3; for the remaining forms shown in the upper part of fig. 4, *s*, *r*, *v*, etc., are not affected in their position by the twinning; but in the absence of the planes bounding the opposite end of the crystal the course of the twinning boundary cannot be accurately defined.

A chemical analysis was made upon about ·5 grams of the sylvanite crystals, which were carefully picked over under the lens until apparently entirely freed from adhering gangue. The analysis shows, however, that considerable of the siliceous gangue was still present. The composition is that of a normal sylvanite, $Au,AgTe_4$.

	Sylvanite.	Cal. to 100%.	Mol. ratio.	
Insol.	1·02			
Au	26·09	26·25	·1334	= 1
Ag	12·49	12·57	·1164	
Te	60·82	61·18	·4894	= 1·96
Fe	1·19			
Total	101·61	100·00		

2. *Crystallographic Identity of Goldschmidtite with Sylvanite.*

In 1899, Hobbs* described goldschmidtite, a new silver-gold telluride, intermediate in composition between sylvanite and calaverite. The analysis was made on a very small amount of material and seemed therefore open to question, but the crystallographic results appeared to place the mineral distinctly

* This Journal, vii, 357, 1899.

apart from others. Through the kindness of Professor Hobbs the writer was entrusted with two of the five type crystals of the new mineral for examination and thus familiar with its appearance, recognized it again in a specimen in the Harvard collection secured some time before from Cripple Creek and labelled as from the Little May Mine. Several measurable crystals were obtained from the latter specimen and they were found to agree in general with the two type crystals of goldschmidtite examined. The author's measurements of Hobbs' two type crystals confirmed in general his results as shown by the table of angles given below but the use of the two-circle goniometer made possible the measurement of a number of minute pyramid planes which Hobbs had been compelled to leave undetermined. These same forms and some additional ones were also found on the new material, thus confirming the identity of the two specimens. These pyramid forms, projected on the goldschmidtite axes, gave symbols far from simple, and unsatisfactory relations with the other forms. They were studied in gnomonic projection, and a comparison of such a projection of the goldschmidtite forms on the clinopinacoid with a similar projection of sylvanite forms showed a striking analogy between the two. By making the orthopinacoid 100 of goldschmidtite equivalent to the orthodome 101 of sylvanite many forms of the first become identical with known forms of the second, and the remainder, while apparently new to sylvanite, receive comparatively simple symbols on the sylvanite axes. In the following table the agreement of angles of the common forms in the two principal zones is well shown.

Symbols Goldschm.	Symbol Sylvanite.	Obs. (Hobbs).	Obs. (Palache).	Calc. (Sylvanite).
100 : 110	=101 : 121	61° 41′	61° 41′	61° 35½′
100 : 210	=101 : 111	42 43	42 56	42 45
100 : 230	=101 : 131	----	70 11	70 10
100 : 310	=101 : 323	31 55	31 40	31 38½
100 : $\bar{1}$01	=101 : 100	55 35	55 15	55 08
100 : 201	=101 : 001	34 13	34 16	34 27
$\bar{1}$01 : 201	=100 : 001	89 48	89 31	89 35
100 : 001	=101 : $\bar{2}$01	89 25	88 38	88 48
100 : $\bar{4}$01	=101 : 201	19 18	19 30	19 20

Much had been learned concerning the crystallographic character of goldschmidtite when the sylvanite crystals above described came to hand, and their study helped to clear up and make certain the relation between the two minerals. The general similarity between the habit and forms of the two series of crystals led to a surmise that a concealed twinning

like that found in the sylvanite crystals was also present in goldschmidtite, giving rise to the many apparently new forms referred to above. And a comparison of the measurements and projections finally proved that this was the case for most of these forms. The following table shows the sylvanite forms equivalent to those observed on goldschmidtite. It will be observed that it is divided into three parts containing (1) forms given by Hobbs and reobserved by the author; (2) forms observed by the author only; and (3) forms given by Hobbs which were not observed on any of the author's material and which lead to new forms for sylvanite.

(1)

Forms observed by Hobbs and Palache.

Goldschmidtite.		Sylvanite.		
Letter.	Symbol.	Letter.	Symbol.	
c	001	*N*	$\bar{2}01$	
b	010	*b*	010	
a	100	*m*	101	
g	310	*t*	323	
f	210	*r*	111	
m	110	*s*	121	
k	032	*θ*	$\bar{2}31$	
w	401	$\underline{n}$	201	twinned
n	201	*c*	001	
s	101	$\underline{a}$	100	twinned
S	$\bar{1}01$	*a*	100	
N	$\bar{2}01$	$\underline{c}$	001	twinned
W	$\bar{4}01$	*n*	201	

(2)

Additional Forms observed by Palache.

Goldschmidtite.	Sylvanite.		
Symbol.	Letter.	Symbol.	
$\bar{2}32$	*e*	110	
232	$\underline{e}$	110	twinned
$\bar{4}34$	*f*	210	
434	$\underline{f}$	210	twinned
$\bar{5}12$	*g*	310	
212	$\underline{g}$	310	twinned
$\bar{1}31$	*R*	120	
$\bar{2}34$	$\underline{\rho}$	$\bar{1}11$	twinned
132	*σ*	$\bar{1}21$	
$\bar{1}32$	$\underline{\sigma}$	$\bar{1}21$	twinned

(2) (cont'd)

Additional Forms observed by Palache

Goldschmidtite.	Sylvanite,		
Symbol.	Letter.	Symbol.	
$\bar{1}34$	*J*	$\bar{3}21$	
$\bar{1}12$	*κ*	$\bar{5}21$	
230	*o*	131	
120	*q*	141	
832	$\underline{I}$	211	twinned
$\bar{5}32$	*i*	321	
532	$\underline{i}$	321	twinned
734	$\underline{j}$	521	twinned
102	M	$\bar{1}01$	

(3)

Forms observed by Hobbs not confirmed by Palache and yielding new sylvanite forms.

Goldschmidtite.		Sylvanite.
Letter.	Symbol.	Symbol.
t	370	292
l	130	161
v	35·0·1	9·0·10 ?
x	10·0·1	403 twinned
q	801	203
r	703	2·0·25 or 301 twinned
y	508	$\bar{7}08$ or $\bar{8}01$ twinned
X	$\overline{10}$·0·1	403
Z	$\overline{14}$·0·1	504

The forms in (3) appear to need confirmation before being added to the sylvanite series as the following considerations will show. None of them was observed by the author on the

twelve or more supposed goldschmidtite crystals from the Little May Mine measured by him nor on the complex sylvanite crystals from the same region. In the absence of definite statements concerning the quality or frequency of occurrence of particular forms in the paper by Hobbs it is difficult to know what weight to assign to these forms. *t*, 292 and *l*, 161, are pyramids of the principal zone of sylvanite and may well be good forms. The seven remaining forms are orthodomes. Of these, two, *q*, 203 and *X*, 403 with its twin, *x*, 403 are probably good forms as they have simple symbols and agree closely in angle with calculated position:

		Meas.	Calcul.
q, 203	∧ 001	24° 37′	24° 20′
X, 403	∧ 001	42 34	42 36
x, 403 twin	∧ 001	26 25	26 24

v, 9·0·10, stands only 2° 20′ from the dominant form 101 and may be vicinal to it; *r*, 2·0·25, is inclined but 3° 10′ to 001, of which it is very likely a vicinal; *y*, $\bar{7}08$, is inclined 3° 27′ to $\bar{1}01$ and may be vicinal to it; lastly *Z*, 504 is inclined 2° 16′ to 403 and might be considered vicinal to that form were it confirmed.

It seems evident in the light of the above facts that so far as crystallographic character is concerned goldschmidtite can not be distinguished from sylvanite but represents a peculiar habit of that mineral, common, as shown in the preceding paper, to the sylvanite of Cripple Creek. Fig. 1 of the preceding paper on sylvanite illustrates fairly well the prevailing habit of goldschmidtite when in the sylvanite position, except that σ, $\bar{1}21$, should be very minute, and most crystals are simple contact twins.

The results of this study were submitted to Prof. Hobbs in the hope that he might be able to complete them by a new analysis of the type material on a larger amount of substance. This proves unfortunately to be impossible, since the specimen from which the type crystals were obtained was only temporarily in his hands and is not now available.

In default of this analysis it was thought that it might be worth while to determine the composition of the supposed goldschmidtite from the Little May Mine, and by sacrificing the whole specimen and carefully picking the crushed gangue material enough was obtained (about 0·4 gram) for an analysis. This purpose was, however, defeated by an accident early in the work, so that only the gold content could be determined. For the sake of comparison this is given below together with that of goldschmidtite and sylvanite.

Little May Mine.	Goldschmidtite.	Sylvanite $AuAgTe_4$.	Sylvanite Cripple Creek.
Au 28·89	31·44	24·45	26·09

While little weight can be attached to a comparison based thus on a defective analysis, still it seems clear that the material studied differs but little from the typical goldschmidtite in composition. On the other hand, while the gold content is high when compared with that of the theoretical $AuAgTe_4$, it should be clearly remembered that no sylvanite with exactly that composition has been as yet analyzed, the gold content actually found varying from 25·87 per cent to 29·35 per cent with proportionately varying silver content. These results seem to show conclusively that the ratio of gold to silver in sylvanite may vary considerably from the theoretic proportion of 1 : 1, without affecting the physical characteristics materially, and it is a question whether it is advisable to attempt to establish species based upon these variations of composition.

Note by Professor W. H. Hobbs.—In view of the results of the investigation by Dr. Palache, above detailed, it seems proper for me to say that the name goldschmidtite should be withdrawn from mineralogical literature as representing a distinct mineral species. Dr. Palache's study shows that goldschmidtite can be referred to the same set of axes as sylvanite, of which it represents a peculiar type. This being true my analysis, which had to be made on an extremely small amount of material, must contain a large error. The method used was the oxidation of the tellurium on charcoal, weighing the button of combined silver and gold, and, after solution of the silver, weighing the gold in the form of powder. The danger of this method lies in the possibility that tellurium will not be completely eliminated and that some silver will oxidize. The button obtained was, however, bright and apparently freed from tellurium. I regret that material is not now available for a second analysis, yet in view of Dr. Palache's crystallographic study of better material, checked as it has been by analysis, no course is open to me but to discredit the results of my analysis.

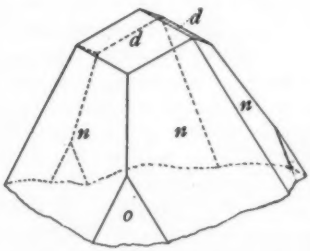
3. *Hessite Crystals from Colorado.*

A specimen of well-crystallized hessite from Boulder Co., Colorado, has been recently acquired by the Harvard Mineral Cabinet from Mr. G. B. Frazer. A description of this specimen is here offered because the crystals present certain interesting peculiarities of habit and because so far as the author has been able to discover no crystals of this mineral from the United States have yet been figured.

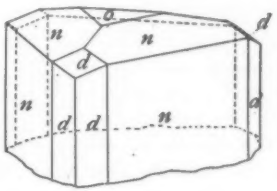
The specimen consists of a small fragment of bluish vein quartz in one side of which is a drusy, quartz-lined cavity. On the quartz walls of the cavity are eight or ten brilliant hessite crystals, a millimeter or less in height, and two small

tufts of wire gold. Two of the steel-gray hessite crystals and a small irregular fragment were detached, the latter yielding before the blowpipe the characteristic reactions of hessite.

5



6



The two crystals (figs. 5, 6) which are shown in about their natural proportions in the figures, presented two entirely different habits, both hexagonal in appearance; but measurements proved them to be isometric and combinations of the three forms:

o, (111); *d*, (101); and *n*, (211).

The hexagonal appearance is due to the development about a trigonal axis, an axis, that is, normal to an octahedral face, and in order to bring out the peculiar symmetry of the distortion the drawings have been made with this trigonal axis vertical, as though the crystals were truly hexagonal.

The difference in habit is due to the fact that different faces of the above forms are developed on the two crystals. In the one, six faces of the trapezohedron equally inclined to the trigonal axis give the effect of a scalenohedron whose summit is modified by a rhombohedron composed of three faces of the dodecahedron, while three octahedron faces form a steeper rhombohedron of the same sign. In the other crystal the habit is prismatic; three only of the six trapezohedron faces parallel to the trigonal axis are developed, yielding a trigonal prism whose edges are beveled by the prism of second order, that is by six planes of the dodecahedron; the termination consists of positive and negative rhombohedrons consisting of dodecahedron and trapezohedron faces respectively, and a single face of the octahedron forming a basal pinacoid.

The two habits were represented about equally on the other crystals in the cavity as far as could be judged without their removal. It should be said that the faces present were sharp and clear and no trace of the missing faces of any form could be detected.

Harvard Mineralogical Laboratory, August, 1900.

Art. XLI. — *New Species of Merycochœrus in Montana.* Part I. By Earl Douglass.

Description of the Skull of Merycochœrus laticeps n. sp.

While making a collection of vertebrate fossils from the Loup Fork beds of the Lower Madison Valley in Montana, I obtained several parts of mandibles, representing three or four different species, which were doubtfully referred to the genus Merycochœrus. Three of the species were remarkable for the depth of the rami. One, which was more slender than the others, possessed characters which made it probable that it belonged to the same genus; though, measuring beneath the middle lobes of the last molars, the deepest jaw was double the depth of the narrower one. I could not identify any of these with species that had been described.

In the summer of 1899 in some clay bluffs near the village of New Chicago in Granite County, Montana, a nearly complete skull and lower jaw with some other bone fragments were found. The jaw was at once recognized as similar to one of those found in the Madison bluffs. The greater part of the skull was enclosed in a clay nodule. From some of the teeth which were exposed it was supposed to be one of the Oregon species of Merycochœrus; but when cleaned from the matrix it was seen to be very different, possessing many peculiar characters which separate it from those forms. It is more nearly related to the type represented by *Merycochœrus proprius* and *M. rusticus*, between which it is intermediate in size.

Its most striking characteristics are the following:

Skull low, broad behind the orbits, narrowing rapidly toward the front and back. Brain case short, the length behind the post-frontal process being about one-half the distance in front of it. Premaxillaries united in front forming a trough-shaped depression, evidently for the accommodation of a proboscis. Maxillaries deeply concave on the sides of the face—this, with the malo-maxillary ridge which widens outward rapidly toward the zygomatic arch, forming a broad nearly horizontal shelf above the posterior premolars and anterior molars. Larger part of external narial opening nearly between the orbits, but continuing forward in a horizontal slit between the maxillaries. Nasal bones short and ascending, placed far back, the anterior tips being about midway between the inion and incisive border. *Foramen infraorbitale* placed farther back than in any other species. Bending down of the face upon the basicranial axis carried to the extreme, the shape of the posterior basal

part of the skull indicating that the head was carried in a nearly vertical or hanging down position. Back part of zygomatic arch small and simple. Length of the alveolar border twice the distance from the last molar to the occipital condyle. Otic bullæ not inflated. Mandible heavy and very deep in the region of the angle. First lower incisor absent. Jaw nearly as deep as skull exclusive of nasals, and nearly as long as the skull at base.

1

Merycochœrus laticeps.
Skull and Mandible, side view, $\times \frac{1}{4}$.

Description of Skull.—The premaxillaries are coössified with the maxillaries. Anteriorly the maxillo-premaxillaries are united for a distance of 5·5^{cm}. Here they form a trough-like depression which becomes broader as it curves gently upward and backward. This widening of the trough is caused by the converging of the ridges from the upper borders of the maxillaries which bound laterally the hori-

zontal wedge-shaped forward projection of the narial opening. and by the conical shape—as seen from the front—of the large convexities in the region of the canines. These convexities have their bases close together in the middle of the incisive alveolar border, make a broad lateral sweep and die out on the face in front of the anterior projection of the malo-maxillary ridge. The first mentioned ridges die out on the anterior inner sides of these convexities a little distance above the alveolar border.

The anterior part of the narial opening begins anteriorly in a rather blunt point, widens gradually as it extends backward and slightly upward for a distance of 3^{cm}, then the sides are nearly parallel and horizontal about the same distance, then it expands and ascends to form the inferior part of the posterior oval opening. This posterior part of the external nares looks forward and slightly upward, thus forming a high angle with the anterior part. Above it is arched over by the short backward sloping nasals. Its lower border is in advance of the orbits, but in front of the bases of the nasals a notch extends back of the orbital border. The vertical height is about 5^{cm}. Between the narial opening and the orbit the tongue of the maxillary curves upward and then backward, apparently ending in a wedge-shaped process between the nasals and the frontals in a plane with the posterior parts of the orbits. The suture separating the frontal and maxillary extends from this point outward and forward and then downward, passing close to the anterior border of the orbit. The skull is a little injured just at the border of the orbit and the orbit is still filled with the matrix so that the lachrymal bone cannot be made out, but it occupies an extremely small space if any in front of the orbit. The malo-maxillary suture continues downward from the orbital border to a line 2·2^{cm} lower than the lower border of the orbit, where it curves forward and downward to near the lower anterior border of the overhanging malo-maxillary ridge. From this place it cannot be traced. The suture where seen is well defined, is complex but forms a quite regular band 3 to 4^{mm} broad. On the roof of the mouth the maxillo-palatine suture appears near the root of the second molar, extends forward and slightly inward to opposite the posterior lobe of *m1*, then transversely across the palate in nearly a straight line. The roof of the mouth is broad and concave. The incisive foramina are confluent, but this is apparently due to the breaking away of the thin median partition, part of the superior portion of which still remains. It now appears as an oval opening, the smaller end being directed backward. Its length is 3^{cm}, and its greatest width 1·5^{cm}.

On the side of the face is a large depression difficult to define. It is nearly triangular in shape. Above its boundary is the median upper border of the maxillary; behind it is the outward expansion of the posterior part of the maxillary in front of the orbit. Beneath is a broad shelf above the malo-maxillary ridge. The anterior angle of the depression is occupied by a deeper elliptical one, the deepest part of which is above the last premolar and the first molar. These two concavities extending inward on opposite sides of the maxillaries make the face quite thin transversely in this region, being in fact only 2·4^{cm} thick, while the skull at its widest place is 20^{cm}. The malo-maxillary ridge dies out on the anterior border of this depression but expands rapidly posteriorly, thus forming the broad shelf above mentioned which is broadest in front but extends outward and backward toward the zygomatic arch. The infra-orbital foramen is large, is near the inferior posterior border of the oval depression above *m2* and looks forward and outward, opening on the horizontal maxillary platform or shelf.

The nasals are nearly triangular if I make out their posterior borders correctly. They are short, extending upward and forward to form the roof of the external nareil opening. They are convex transversely and longitudinally and are pointed in front. These points are about midway between the incisor and the inion.

The orbits are oval with the larger end upward. The posterior inferior border is nearly straight or a trifle convex, but this may be due to a slight displacement of the post-orbital process of the malar. Only one orbit is preserved.

What I take to be the boundary between the nasals and frontals is a line where the bone is broken. It passes from the posterior angle of the maxillary transversely and somewhat backward to the suture between the nasals.

The frontal appears to meet the malar posterior to the orbit at the median line, where there is a roughening on the narrow isthmus of bone. From the upper posterior border of the orbit the supra-orbital ridges converge rapidly backward and then less rapidly, uniting to form a prominent narrow sagittal crest. The form of this part of the skull back of the nasals and including the upper part of the brain case is almost like that figured in Bettany's paper, "On the Genus Merycochœrus," as *M. temporalis;* but the supra-orbital foramina occupy a different position. In the present species they are above a line uniting the posterior borders of the orbits, are far apart, have no grooves leading into them, and are a little nearer the median line of the skull than the outer border. The tempero-parietal suture extends upward and backward until, beneath the anterior part of the sagittal crest it curves downward and

then upward again, passing just beneath the foramina at the base of the inion. These foramina are not the same on opposite sides of the skull. They are farther forward and farther apart on the right side of the skull and are more uniform in size. On the left side the anterior one is circular and several times larger than the one which is a little behind and beneath it. Just posterior to this smaller foramen the parieto-occipital suture extends upward to the broken sagittal crest. The temporo-occipital extends backward and downward but is lost on the broken border. The ridge near the parieto-squamosal suture extends from the larger foramen above mentioned, downward and forward, at first coinciding with the suture and then running beneath and nearly parallel to it. The brain case on each side of this is broadly concave. The brain case is short antero-posteriorly and slopes downward quite rapidly behind the forehead, though the sagittal crest evidently continued nearly on a level.

The crest of the inion is broken but was considerably posterior to the occipital condyles. The wing-like expanses extending to the zygomatic arch were broad and thin. Just above the foramen magnum the occiput is broadly convex; but a short distance above a depression begins on the median line, becomes broader and deeper and then shallower to near the crest of the inion. The ridges that bound this concavity separate it from larger lateral concavities situated farther down. These concavities are bounded above by the wing-like expansions above mentioned and outwardly by the broad convex post-tympanics which appear as large swellings on the sides of the occiput. This post-tympanic with the horizontally expanded portion of the squamosal above and the long posterior flat surface of the post-glenoid encloses a quite large triangular cavity, the post-tympanic and post-glenoid nearly coming in contact below. The meatus auditorius externus evidently did not fill all this space, but the shape cannot be definitely made out on account of the matrix and injury of the bone; but it passes inward and forward a distance of 4^{cm} to connect with the otic bullæ.

As seen from below, the foramen magnum is lenticular in section and its transverse is double its antero-posterior diameter, being respectively $2{\cdot}5^{cm}$ and $1{\cdot}2^{cm}$. With a line joining the incisive border, the lower extremities of the pterygoids and the occipital condyles, this opening forms an angle of about 65°. The occipital condyles are also narrow antero-posteriorly, the diameter being only $1{\cdot}7^{cm}$ in this direction while the transverse diameter is $6{\cdot}1^{cm}$. The anterior articular faces are much deeper and broader than the posterior ones and they are partially

separated by an angle. The anterior faces are separated by an excavation 1·5^{cm} wide while the posterior ones are 3^{cm} apart.

The basi-occipital and basi-sphenoid ascend at a steep angle. This with the upper contour of the skull makes the brain cavity very small. Beneath the forehead the basi-sphenoid bends forward and becomes nearly parallel with it. The basi-sphenoid is angulate for a short distance between the glenoid surfaces.

The paroccipital processes are broken off at about a level with the lower points of the occipital condyles, but they appear to have been much longer. They are broad transversely but rather narrow antero-posteriorly. At the bases they are nearly crescent-shaped in cross-section. The more convex portion faces inward and backward, while the concave area faces forward and outward. The outer portion is a wing-like expansion of the more robust inner part, which slants forward and outward from the occipital condyles, forming with them an angle of 65°. The anterior inner horns or lobes are in a line with the post-glenoids. Just in front of these horns and closely in contact with them at the bases but with their anterior bases higher are the prismatic tympanic bullæ. These bullæ are not inflated but quite long vertically, especially on the anterior inner side, and do not extend much below the posterior bases of the paroccipitals. The shape of these bullæ is nearly that of a quarter of a cylinder terminated by a cone, the angle joining the nearly plane or slightly concave faces being directed outward and backward.

The post-glenoid processes are of moderate length and transverse breadth, are flat behind and moderately convex in front. The outer border slopes outward and upward, dying out on the inferior posterior surface of the zygomatic arch, which slopes upward and backward from the glenoid surface. This surface is slightly concave, being bounded exteriorly by the ridge on the lower outer border of the arch. The glenoid surface is broad transversely (6^{cm}) and uniformly convex antero-posteriorly.

The posterior angle of the zygomatic arch is on a line with the anterior borders of the paroccipital process, and extends upward to the line of the lower border of the orbit.

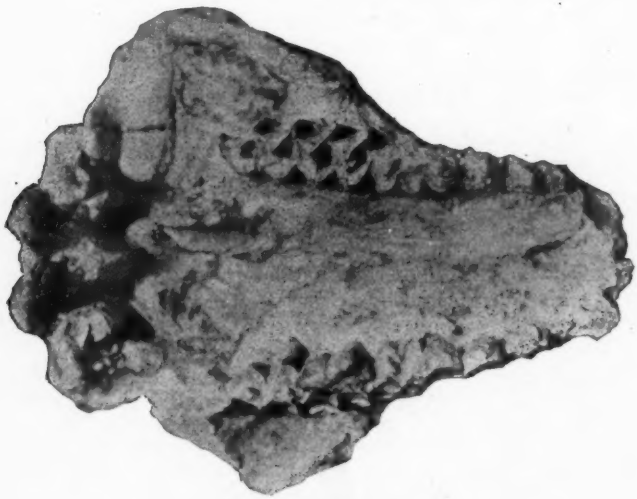
The malar has four approximately equal sides if the upper is measured along the border of the orbit; though the lower is longer in a straight line. The vertical width below the orbit and the antero-posterior length just below it are nearly the same. The upward extension in front of the orbit is narrower than the post-orbital process.

The palatines and pterygoids extend about 2·9^{cm} back of the last molars. It is only 2^{cm} from the posterior edges of the pterygoids to the anterior faces of the otic bullæ. This

approximation is due to the extreme shortening of the posterior basal elements of the skull so that the post-glenoid and par-occipital processes, the occipital condyles and otic bullæ occupy a comparatively narrow transverse zone.

Between the posterior lobes of the last molars the palato-pterygoid lobes extend downward and backward until they reach a point about on a level with the incisive border and the lower extremities of the occipital condyles. They formed a median trough extending downward and backward from the palate.

2

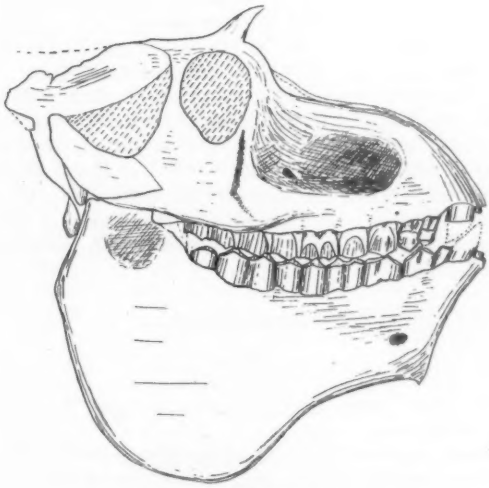


Merycochœrus laticeps.
Skull, view of under side, nearly $\times \frac{2}{3}$.

Lower Jaw.—The rami were not coössified at the symphysis, and in the present specimen they are slightly spread apart. The anterior border is concave downward and nearly uniformly convex transversely. The *foramen mentale* is beneath *pm 3*, as is also the angle of the chin. At this angle a small process projects downward. Back of this the lower border of the ramus curves slightly upward and then downward to a point beneath the posterior part of *m 3*. At this point it is twice the depth of the shallower part under *m 1*. Back of this the posterior border ascends with a steep curve to a point 4·5^{cm} below the top of the condyle, where it ascends nearly vertically to the condyle, forming a low angle (about 25°) with the continuation

of the posterior border. The posterior border is slightly raised laterally. The condyle is not quite so broad transversely as the glenoid surface with which it articulated and is more narrowly convex antero-posteriorly. The masseteric fossa descends only a short distance—to a line connecting the base of the lobe of *m 3* and the posterior angle above mentioned. The bone is injured in the region of the coronoid process so its form cannot be made out. A broad convexity begins at the posterior part of *m 3*, extends forward and downward to the anterior lower border of the ramus, branches at the mental foramen and continues to the alveolar border at *pm 2*, thus leaving a depression under *pms 3 and 4* amd *ms 1 and 2*. The length of the dental series is two-thirds the length of the jaw.

3



Merycochœrus laticeps.

Skull with jaw, $\times \frac{1}{4}$.

The mandible is too far ahead on account of slight forward displacement of post-glenoid process.

Dentition.—Superior: The crowns of the incisors and canines are not preserved. The upper incisors were small, quite close together and in a transverse row. The roots of the first and second are laterally compressed. They were nearly the same size, but the third was a little larger. In cross-section the roots of the canines are three-sided with rounded angles, the posterior side being the broadest: *Pm 1* is com-

pressed longitudinally, is inserted diagonally by two roots, and the posterior part overlaps *pm 2* outwardly. *Pm 2* is considerably worn, but there is still a shallow oblique enamel lake near the posterior margin. *Pm 3* has a longitudinal lake with two pits, near the inner border of the tooth. *Pm 4* is like the corresponding tooth in *Merychyus elegans*. The posterior lobe on the last molar is not developed as in the *Merycochœrus proprius;* though the posterior horn of the posterior external crescent is convex behind, it is narrower and extends much more outward than in that species. The premolars and molars are all longer than in *M. proprius*. This is due in part, but I think not wholly, to less amount of wear.

Inferior: There is no trace of a first incisor. The second and third are laterally compressed at the roots, and are 2^{mm} apart. They were about the size of upper incisors one and two. *I 3* is set obliquely close to the canine on its anterior inner side and a little more anteriorly than *I 2*. The canine is small, but a cross-section at the root is nearly the same in form as the upper canine. *Pm 1* is much larger than the lower canine. It has a longitudinal groove on the outside of the root. The *crowns* of the above teeth are not preserved. *Pm 2* is more oblique than in *M. proprius* or *M. rusticus*, being closely crowded between *pms 1 and 3*. *Pm 3* is porportionally narrower posteriorly than in the former species, judging by Leidy's figure. In *pm 4* the posterior fossa is more oblique, opening on the posterior inner angle instead of on the posterior border.

Measurements.

SKULL.

	M.
Length of skull from incisive border to posterior of occipital condyles	·245
Length from incisive border to back of pterygoids	·185
Length from incisive border to front of otic bullæ	·203
Width of skull at glenoid articulation	·200
Width at middle of last molars	·180
Width at third premolars	·080
Width at canines	·057
Width of palate between last molars	·063
Distance from anterior tips of nasals to incisive border, measured in a straight line	·166
From tips of nasals to crest of inion, about	·150 to ·160
Distance from front of orbit to incisive border	·135
From front of orbit to back of occiput	·150
Diameter of orbit, antero-posterior	·038
Diameter of orbit, vertical	·045

	M.
Width of top of skull above orbits	·118
External nares, greatest width	·044
External nares, greatest length	·112
Length of three upper incisors	·015
Length of dental series from front of canine	·153
Length of molar-premolar series	·136
Length of premolar series	·056
Length of molar series	·080
Width of last molar	·030

LOWER JAW.

	M.
Length of jaw, greatest	·235
Depth at chin	·057
Depth under m 1	·053
Depth under back part of m 2	·063
Depth under last lobe of m 3	·109
Length of inferior dental series	·157
Length of molar-premolar series	·150
Length of premolar series	.058
Length of molar series	·092
Space occupied by i 2 and 3	·008
Width of canine at alveolus, transverse	·009
Length of canine antero-posterior	·0065
Width of pm 1	·011
Length of pm 1 antero-posterior	·014
Length of pm 2	·014
Width of pm 2	·006
Length of pm 3	·017
Width of pm 3	·0095
Length of pm 4	·0185
Width of pm 4	·012
Length of m 3	·044
Width of m 3	·0165
Length of foramen mentale	·008
Width of foramen mentale	·005

From the parts of *Merycochœrus proprius* that have been described *M. laticeps* differs in the lateral aspect of the maxillaries; the smaller size and, apparently, the more transverse position of the incisors and incisive border; the absence of a space between *pms 1* and *2;* the more hypsodont character of the teeth; the more posterior position of the infra-orbital foramen; the smaller size and different shape of the small posterior lobe on the last upper molar; and the different shape of the mandible, especially its greater posterior depth.

M. rusticus approaches more nearly to the present species in the facial concavities, in the size and position of the incisors,

and the trough-like shape of the maxillo-premaxillaries above; the crowding together of *pms 1* and *2;* and possibly in the posterior deepening of the mandible. But, as will be seen by comparing the present descriptions with Leidy's figures and descriptions, the face and anterior border are quite different in the two species. In *M. rusticus* the anterior part of the face as viewed from the side rises more abruptly for a short distance and then more gradually backward. The form of the concavity on the side of the face is different; the infra-orbital foramen and the anterior inferior root of the zygomatic arch are farther forward; the latter also is higher as is also the lower border of the malar. The space between the upper canine and first premolar is greater and *pm 1* does not overlap *pm 2.* The mental foramen is longer and the chin is less concave, the protuberance at the chin is larger and longer, and the anterior inferior border of the jaw is more nearly straight. *M. rusticus* is smaller than *M. laticeps.*

ART. XLII.—*On Mohawkite, Stibio-domeykite, Domeykite, Algodonite and some artificial copper-arsenides;* by GEORGE A. KOENIG.

THE knowledge of the existence of copper arsenides in the Keweenaw copper formation is nearly as old as the mining operations in this region themselves. In the matter of occurrence there are two points to be noted: (1) The arsenides are not found in the bedded deposits of native copper, but always in fissures, intersecting the beds. (2) These veins have thus far only been observed in the lower beds, near the foot of the formation to the southeast. Arsenic, however, is found in the smelted and refined copper of all the mines. This element is a minimal amount in the copper from the Great Conglomerate of the Calumet and Hecla mine and becomes a maximum in the copper from the amygdaloid beds of the lower measures, on which the Mohawk, Wolverine, Arcadian, Sheldon-Columbia, Isle-Royale, Atlantic, Baltic, Champion, etc., are located. The Sheldon-Columbia location near the shore of Portage Lake in the village of Houghton was the first mine which furnished copper arsenides, notably domeykite. The larger part of the specimens in collections come probably from this mine. Whitneyite was found in a quartz vein in dark melaphyr, not far from the present Mohawk, but the existence of any copper rock was not suspected at that time at that point. Several masses of domeykite have been found in the drift on the Hancock shore of Portage Lake, very much decomposed, cuprite and arsenates being the chief products. In the spring of 1898 the opening of a new street in East Houghton on the old Sheldon-Columbia location, disclosed a quartz vein containing some foliated domeykite. Many good specimens were gathered and have come into collections. A similar vein has been known for years on the old Huron location, now the southern end of the Isle-Royale property. Algodonite was found in the Pewabic mine, located on the Quincy amygdaloid bed and which lies about 5000 feet higher than the Isle-Royale amygdaloid. In developing the Mohawk property a cross vein at right angles to the copper-bearing amygdaloid was met in December, 1899. This cross vein was from 12 to 15 inches wide when struck, but has since shown very varying dimensions. In a gangue of quartz and calcite the copper arsenides have been found in this vein more abundantly than in any of the locations mentioned above. Early in January Mr. Fred. Smith, Superintendent of the Mohawk mine, sent me a solid piece weighing from 4 to 5 pounds, with the request to make

a thorough investigation and report. On January 18th I reported to Mr. Smith that the mineral substance which he had sent me was a new mineral species which I would call *Mohawkite.* Later on I received other material from Mr. Smith in which I identified an antimonial domeykite for which I propose the name *Stibio-domeykite*, and also some very peculiar intimate mixtures of Mohawkite with Whitneyite. It appears that the Stibio-domeykite is the more prevalent of the arsenides, and not the Mohawkite as was thought at the start. The vein has since been traced to the outcrop where it was found to form a ridge owing to the quartz in the gangue.

1. *Mohawkite.*

Physical properties.—Form is massive; no crystallization of any sort has been observed. The structure is mostly fine granular, sometimes compact. The color on fresh surface is gray with a faint tinge of yellow. Tarnishes very easily, and the tarnish is apt to be ultimately dull purple. A yellow brassy tarnish is brought about by boiling, though in cold water the original color lasts for two days and more. The color is, however, no sure guide for identification. The mineral is very brittle, and owing to the granular structure is not possible to fix the degree of hardness; it is approximately 3·5. Spec. gr. at 21° C. (in boiled water but without corrections) = 8·07, mean of three closely agreeing trials and with perfect material, of which there was plenty,—4.6294 grams were taken.

Chemical properties.—In closed tube gives no sublimate of arsenic; only a slight sublimate of As^2O^3, owing to the air in the tube. The substance melts in the tube at cherry heat, and colors the glass blue if the heating be kept up for a few minutes (Cobalt). In the open tube the reactions are similar but more pronounced owing to the vigorous oxidation. On charcoal in O. F. copious vapors of As^2O^3, odor of arsenic and ultimately a globule of metallic copper. If a fragment of the mineral be placed in a shallow cavity on charcoal, along side of a borax bead of equal size or somewhat larger, and both fused together in the point of the blue flame, so that the metallic globule be exposed to the air, then the borax bead will assume the pure blue color of cobalt. If this treatment be kept up for sometime and a fresh borax bead be taken every minute, then a brown nickel bead will be obtained and finally a blue or red copper bead; thus proving all the metals present except the trace of iron. This test (Plattner's) should be used always in examining metallic arsenides. Thus the mineral contains copper, nickel, cobalt, iron (trace) and arsenic. Boil-

ing concentr. nitric acid dissolves the mineral without leaving a residue, forming first a green, then a murky blue solution (owing to the interference between nickel-nitrate green and cobalt-nitrate red). HCl does not act upon the mineral. The quantitative analysis was made by several methods:

(*a*) Nitric solution made ammoniacal, alcohol added and magnesia mixture. This is not a good method, because part of the nickel and cobalt enter into the magnesium-ammonium arsenate.

(*b*) Nitric solution made ammoniacal, diluted properly and H^2S passed into hot solution to saturation. Filtrate evaporated to dryness, residue oxidized with HNO^3 and magnesium-ammonium arsenate precipitate. Separation of copper from nickel and cobalt by H^2S; separation of nickel and cobalt by nitrite method.

(*c*) Powder fused with nitrate and carbonate of sodium. This gives very good results for arsenic; but for the fine pulverulent condition of the oxides these latter must be carefully handled to avoid loss.

I find that the magnes. amm. arsenate can be heated on the asbestos pad of a Gooch crucible without loss into pyro-arsenate. From four analyses of perfect material I obtain

Cu	61·67
Ni	7·03
CoO	2·20
Fe	trace
As	28·85
	99·75

hence the atomic ratio

Cu	0·9803		
Ni	0·1200		
Co	0·0373		
	1·1376	2·958	$(Cu, Ni, Co)^3$
As	0·3847	1·000	As

This is an exact ratio of 3 : 1, the ratio of domeykite. I look upon this as a case of isomorphic replacement. We may expect to find all gradations of replacement within the ratio of 3 : 1. Synthetic experiments lead me to consider this ratio as representing an especially strong one, as of bonds well satisfied; because I have been enabled to obtain it artificially in well defined crystals, of which more hereafter. The molecule Cu^3As is the strongest of all, the other ratios seem to partake more of the nature of alloys, of unsatisfied bonds. It may be urged that a mechanical mixture of the copper arsenide with

nickel-cobalt arsenide is here presented. Against such a view speaks the physical condition of the substance in the first place and also that a ratio of $(Ni, Co)^3As$ has not been observed so far. The question presented itself at once as to whether any of the domeykite occurrences in Houghton Co. contain nickel and cobalt. Winkler gives this metal in the Zwickau occurrence at 0·44 per cent. F. A. Genth does not mention it, and even from the Michipicoten Island location where niccolite accompanies it, the nickel is absent in the domeykite. I have examined every accessible specimen qualitatively. Neither nickel nor cobalt could be found by Plattner's test; but nevertheless it is very probable that all domeykite contains both metals in traces, as my careful analysis of the mineral from the Sheldon-Columbia location, both old and recent, demonstrates. From 0·5 gram of substance just sufficient cobalt oxide was obtained to give color to 50 mg. of borax glass and the nickel was proved by reducing the bead with tin on charcoal. Another matter engaged my attention at once, namely the discrepancy in the specific gravities given by the several authors and recorded on page 44, Dana Min., 6th edit. These densities vary between 6·70 and 7·547 against my determination of 8·07 for the Mohawkite. The collection of the Michigan College of Mines contains one fine specimen of domeykite from the Sheldon-Columbia mine. The material is very uniform, a few specks of calcite the only visible gangue. Of this 3·8559 grams were selected. The specific gravity at 21° C. was found = *7·9486*. The whole material was then dissolved, no residue was left and in a part of the liquid calcium was looked for, but only a trace was found. Hence we have every reason to take this specific gravity as that belonging to domeykite; the figures in the literature must be wrong. It is true that the analysis of this substance does not agree with the theoretical composition exactly, namely:

Cu	74·00	Spec. gr. found	7·9486
(Fe, Ni, Co)	0·06	" calculated	8·1020
As	26·14		
	100·20		

Now if we assume that the elements in this combination possess the same specific gravity as they do in the free state, we may calculate the specific gravity. If specific gravity of Cu = 8·96 and of As = 5·63 then the above composition must weigh $8·96 \times 74·00 + 5·63 \times 26·14 = 8·1020$. The specific gravity of the theoretical Cu^3As will be = 8·017. For Mohawkite the calculated specific gravity will be, taking Co = 8·96 and Ni = 9·5 (the highest number on record):

Cu	=	61·67	× 8·96	= 5·5256
Ni	=	7 03	× 9·5	= 0·6678
Co	=	2·02	× 8·96	= 0·1809
As	=	23·85	× 5·63	= 1·6242

7·9985
8·0650 found

+0·0665 difference

This is quite a satisfactory agreement. Yet it occurred to me at this stage of the investigation to verify the relations between specific gravity and composition by artificial compounds and also to see in how far domeykite might be obtained in crystals.

A combustion tube was closed at one end over the lamp. Resublimed arsenic, roughly powdered, was placed into the bottom to the amount of 7·9 grams. On top of this was poured 20·0 grs. of copper filings. The latter had been the end product in a determination of oxygen in refined copper. Total non-copper in this material 0·07 per cent, consisting of arsenic and iron. An asbestos plug was put over the copper and the tube placed in horizontal position into an Erlenmeyer combustion furnace. The copper was first heated to a dull cherry redness and then the arsenic was heated to the sublimation temperature. The heating was kept up for two hours, the open end of the tube being provided with a mercury valve to prevent any air currents from entering the tube. The copper absorbed the arsenic with avidity. One could see that only the part nearest the vapors changed in color and 30 minutes from the beginning this front portion began to melt off. After all the arsenic had become volatilized and a considerable part of the liquid compound had been formed the temperature of this liquid was raised to bright redness and kept so until the end of the experiment; it being 6 o'clock P. M. The tube was inclined so that the liquid covered the solid portion and left to cool slowly. In the morning three distinct substances were found. A dark colored fused mass, then a porous gray part and then the apparently unaltered copper filings, merely slightly caked together. (*a*) The dark, fused portion. On the fracture blue-gray color; strongly developed radial structure and, in fact, so closely resembling chalcocite that one could not tell by the eye one from the other. The weight of all three parts was 27·27 grams. The weight of the unaltered (apparently) part was 9·65 grams; hence in the altered part there must be approximately 10·35 of copper and 7·2 grams of arsenic, giving an atomic ratio of 9·6 : 16·4. Now if the quantities taken of copper and arsenic were in the ratio of 3 : 1 it is

evident that at red heat the two elements form the compound Cu^3As, leaving much copper unaffected. The specific gravity of this fused arsenide was found at 7·71, (3·8837 grams being taken). The analysis gave

		Calculated for Cu^3As.	
Cu	63·30	Cu	62·69
As	37·00	As	37·31
	100·30		100·00

The calculated specific gravity is = 7·754, giving a minus difference of 0·044 against the actual specific gravity.

(*b*) The porous zone between *a* and the unaltered copper. An ordinary lens showed that this mass consisted of groups of minute crystals, exhibiting very brilliant faces. A power of 50 diameters differentiated the crystals easily. They appear to be combinations similar to those of arsenopyrite. Believing that I had found the method by which these crystals could be prepared readily I destroyed them before making an attempt at measurements, leaving only one group, and this one was lost clumsily. There are still crystals on the copper cylinder showing the forms and building up of the grape-like bunches but I do not consider them worth the trouble connected with micro-goniometric work. 253 milligrams of these groups, which separate easily from the base, were taken for analysis and only the copper was determined, as there could not be anything but it and arsenic in the material. Found

$$Cu = 71·39;\ \text{theoretical for } Cu^3As = 71·6\ Cu$$

No doubt can exist as to the identity of these crystals with domeykite. I have made several attempts since to get the crystals but evidently did not hit the right temperature again. I obtained domeykite as crystalline mass. In one experiment I melted together 28·886 grams of the Cu^3As with 7·8 grams of copper in a glass tube. Liquidity maintained for one hour. After cooling the column was found of varying composition from bottom up. The bottom portion showed a fracture similar in color and structure to white iron, with a faint yellow, in fact it looks exactly like the domeykite of Houghton Co. Specific gravity = 8·05; percentage of copper = 75·4, considerably above the ratio Cu^3As; calculated specific gravity=8·085.

Above this was found a laminated or scaly zone, resembling some of the recently found domeykite from Sheldon location. It gives copper = 71·14, very close to Cu^3As.

The top portion resembles in color and structure (very fine grain) the Cu^3As. It gives copper = 64·8.

2. *Stibio-domeykite.*

With this name I propose to designate the domeykite from the Mohawk mine, Keweenaw Co., and any other locality where mineral of similar composition will be found. In physical properties it is undistinguishable from the domeykite of the Houghton Co. mines. It is remarkable for the massiveness of its occurrence, the freedom from admixtures. It has a decided subconchoidal fracture and takes on a brass tarnish very soon, which, however, ultimately turns into bluish purple. It is very brittle but not as friable as the Mohawkite. Its hardness is very near 4, a little below.

Specific gravity at 21° C.= 7·902 (made with 4·5595 grams) B. B. In the open tube after heating the molten globule for five minutes one observes the forming of yellow spots near the globule and a slight ring or patches farther on, which turn yellow on applying higher heat and volatilize in part. Farther on there is a copious sublimate of arsenic trioxide. If now one washes out the tube in a jet of water and passes H^2S into the tube one observes the above ring and patches turn red, whilst the arsenic oxide turns gold-yellow. I was astonished myself to find that one could demonstrate thus the presence of 0·1 per cent antimony in the mineral. On charcoal blow the point of the oxidizing flame upon the melting mineral for two minutes, then drive off the white arsenic with a gentle flame, the antimony trioxide remains. The open tube reaction is preferable and certain. Concentrated nitric acid does not dissolve the mineral completely; a white cloudiness or a white sediment will be left. When fused on charcoal alongside of a borax bead, the latter colors greenish after several minutes' action (cobalt and nickel cannot be thus found, though present in small amount).

The analysis gave (type specimen):

Cu	72·48
(Fe, Ni, Co)	0·24
As	26·45
Sb	0·78
	99·95

This is evidently a typical domeykite, and one would expect likewise that the percentage of antimony is variable. In order to ascertain this I took twelve pieces, all over one pound each, and treated one gram of each with 10^{cc} of concentrated nitric acid, boiling until the color was blue, then added 15^{cc} of water to each and stood the beaker glasses in a row. (The type specimen with its 0·78 antimony was among the lot.) It appeared that all contained antimony, but no two

an equal amount. Some showed more, some less than the type specimen. I selected the one with the heaviest sediment and determined the antimony as trisulphide. It gave Sb = 1·29. This must be taken as the maximum until other tests show greater amounts. The Houghton domeykites show no trace of antimony.

3. *Mohawk Whitneyite.*

With this name I shall designate not a species, nor even a variety but simply a most intimate mixture of the two species Whitneyite and Mohawkite, of which considerable masses are at present encountered in the Mohawk mine. This material is distinguishable at once to the layman even. It is very tough and approaches Whitneyite in that respect. Ordinary blows with the hammer fail to break the masses, the chisel is often required and the hammer leaves a dent as in soft metal. The fresh fracture is gray, fine granular, even hackly. These fractures assume a dull brown or olive-green tarnish, much like algodonite and Whitneyite. There are, of course, all gradations, from nearly pure Mohawkite to nearly pure Whitneyite. The material looks homogenous, but is not, as the following analyses show. The samples were broken with the chisel in close proximity to one another.

No. 1.		No. 2.	No. 3.		No. 4.	
Cu	85·36	83·61	Cu	79·36	Cu	84·86
(NiCo)	0·32		Co	0·82	(Ni+Co)	0·64
(by diff.) As	13·59		Ni	0·61	As	13·06
$CaCO^3$	0·73		Fe	0·36	$(CaMg)Co^3$	0·71
	100·00		As	15·07		99·27
			$CaCO^3$	2·41		
			$MgCO^3$	0·60		
				99·23		

A notable fact is that in No. 3 the cobalt exceeds the nickel. Calcite is the gangue of this material. All manner of atomic ratios can be calculated from these analyses.

No. 1	has the ratio	$Cu^{7.5}As$
No. 2	"	$Cu^{6.7}As$
No. 3	"	$Cu^{6.45}As$
No. 4	"	$Cu^{7.7}:As$

In connection with these results, attention may be called to a communication made by Mr. J. Stanton, Secretary of the Mohawk Mg. Co., to the Engineering and Mining Journal of April 7, 1900. Mr. Stanton here gives Dr. Ledoux's report upon some of the Mohawk mineral. Dr. Ledoux figures from

his analysis the ratio Cu_4As (including Ni+Co) and says that with this formula Mohawkite will probably be accepted by science. If this ratio does exist then it is *not* Mohawkite; for this name was given by me to Cu^3As (including Ni+Co). But the following sentence regarding the material induces me to believe that it was a mixture of Mohawkite and Whitneyite. The report says: "The sample was pulverized and concentrated by washing until under a powerful glass no other minerals were present. Thus purified the mineral was analyzed with the following result: Cu = 68·6; As = 22·67; Ni = 6·55; Co = 1·2; Fe = 0·23; S = 0·53. The sulphur and iron are impurities [why? if the powerful glass showed no other minerals present? Koenig] and it is also reasonably probable that the nickel and cobalt are mechanically mixed in the sample, although it is possible that some of the copper has been replaced by nickel and cobalt." How can Dr. Ledoux calculate a formula at all if he holds such views as here expressed? He gives the specific gravity at 7·8, but as I have shown above, a composition such as he finds must have a higher specific gravity even than I find for the Mohawkite proper, namely 8·140, leaving out both iron and sulphur. The atomic quotients of Dr. Ledoux's percentages are:

Cu.....	1·089	As.....	0·302
Ni.....	0·111		
Co.....	0·020		
	1·220		

giving the ratio of 4:1, but if nickel and cobalt are thrown out the ratio is nearer 3:1 than 4:1.

Under the existing conditions I permit myself to doubt the existence of a molecule (Cu, Ni, Co)^{4}As and merely present the facts to the mineralogical public.

4. *Algodonite.*

This species has not yet been observed at the Mohawk mine, though some of the Mohawk-Whitneyite resembles it very much. I was induced to bring it within the present investigation merely by the specific gravity, which is given by Dr. F. A. Genth as the only authority at 7·62. To Dr. Lucius Hubbard I am indebted for the material. This gentleman possesses a handsome specimen from the find at the Pewabic mine, many years ago. The specimen looks like the segment of a nodular piece. It showed the chocolate-brown dull tarnish. But the fresh fracture is beautiful. It has a color and texture exactly

like razor-steel. Although very tough, it does not dent like Whitneyite. The nodule was covered with Whitneyite and this mineral shows on Dr. Hubbard's specimen like a thin fringe around the algodonite. I could break off some 5 grams of faultless material. The specific gravity was found at 21° C. = 8·383 (using 3·8418 grams). The analysis made with 0·5 gram. Of silver I could find no trace. The analysis gave

Cu	83·72	for Cu^6As	
(Fe, Ni, Co)	0·08	Cu	83·5
As	16·08	As	16·5
	99·88		

Calculated from these figures, the specific gravity is 8·406. This gives a minus difference of 0·023 from my experimental value of 8·383.

Michigan College of Mines, June, 1900.

ART. XLIII.—*Heat of Solution of Resorcinol in Ethyl Alcohol;* by C. L. SPEYERS and C. R. ROSELL.

WHEN a system undergoes a change depending upon an absorption of some particular energy, then as the intensity of that particular energy is increased on the outside of the changing system, the amount of change inside the system is increased; when the system undergoes a change depending upon a rejection of some particular energy, then as the intensity of that particular energy is increased on the outside of the changing system, the amount of change inside the system is diminished. This statement is to be considered as universally true though now and then a seeming exception comes up.

The latest seeming exception that we have come across is resorcinol with ethyl alcohol. Resorcinol dissolves in a large excess of ethyl alcohol with rejection of heat* and yet the solubility of resorcinol increases with the temperature. That is, a change depending upon a rejection of heat energy seems to be favored instead of being hindered, by increasing the intensity of the heat energy on the outside of the system.

But the mistake lies in joining a heat of solution in a large excess of solvent, giving a very dilute solution, to a solubility which implies a saturated solution and one more or less concentrated. The two solutions must be of equal concentration. Wherefore the heat of solution in a nearly saturated solution is the quantity that must be used, and its sign alone is enough, its value is not needed, to test the validity of the above statement.

The sign can be found by diluting a saturated solution with a small quantity of pure solvent. The method by supersaturation fails for resorcinol, does not crystallize fast enough from a saturated solution even to get the sign; at least it did not do so in the calorimeter we used.

About 200^{cc} of saturated solution at about 27° were diluted with about 10^{cc} of pure solvent. The temperature rose more than 0·2°.

The act of solution may be separated into two parts; namely, one in which the solute liquefies, which always involves a gain in energy to the system and is +, the other in which the liquefied solute mixes with the rest of the liquid to form the desired solution. The second part may be + or −; when it is + then obviously the whole heat of solution must be +. And this is the case for resorcinol, because concentrating a

* Speyers, Journ. Am. Chem. Soc., xviii, 146, 1896.

nearly saturated solution absorbs heat, and the heat of fusion is +.

Consequently the above statement does express the behavior of resorcinol with ethyl alcohol so far as heat of solution and solubility are concerned.

Since heat is rejected when resorcinol dissolves in a large excess of ethyl alcohol and since heat is absorbed when it dissolves in a small quantity, the temperature should not change when these substances are mixed in some certain proportion. This proportion was found to be about 6 grams of resorcinol with about 100 grams of ethyl alcohol.

The solubilities in all the following 37 cases increase with the temperature and so the heat of solution of all the solids in a nearly saturated solution should be +. This demands that the heat of fusion should be larger than the heat of mixing the liquid solute and solvent whenever the sign of this latter heat is −.

The signs refer to the heat of dilution of a saturated solution with about 5 per cent or 10 per cent of pure solvent.

	H_2O	CH_3OH	C_2H_5OH	C_3H_7OH	$CHCl_3$	C_7H_8
Urea	+	----	±	----	----	----
Urethane	+	+	+	+	−	+
Chloral hydrate	−	----	−	----	+	+
Succinimid	+	----	±	----	----	----
Acetamid	−	----	+	----	----	----
Mannitol	±	----	----	----	----	----
Resorcinol	+	----	−	----	----	----
Benzamid	----	----	±	----	----	----
p-Toluidin	----	---	+	----	----	----
Acetanilid	----	−	±	----	+	----
Acenaphthene	----	±	±	±	−	−
Naphthalene	----	−	±	−	−	−
Phenanthrene	----	----	±	----	----	−
Cane sugar	−	----	----	----	----	----

Rutgers College, Sept. 1, 1900.

Art. XLIV.—*The Sulphocyanides of Copper and Silver in Gravimetric Analysis;* by R. G. Van Name.

[Contributions from the Kent Chemical Laboratory of Yale University—XCIX.]

Cuprous Sulphocyanide.

As early as 1854 attention was drawn by Rivot* to the possibility of estimating copper gravimetrically by weighing as cuprous sulphocyanide, and to the advantages which the process afforded in separating copper from other metals. Rivot's method of procedure consisted in dissolving the substance to be analyzed in hydrochloric acid, reducing the copper with hypophosphorous or sulphurous acid, and precipitating with potassium sulphocyanide. The precipitate dried at a moderate temperature was weighed as cuprous sulphocyanide and then as a control converted by ignition with sulphur into cuprous sulphide and weighed in that condition.

In his well known work upon quantitative analysis Fresenius in one place† denies the practicability of the direct weighing of copper as cuprous sulphocyanide on account of the tendency of the latter to hold water even when heated to the temperature of incipient decomposition. As authority for this statement he cites Claus,‡ who found 3 per cent of water in the precipitate after drying at 115°, and Meitzendorff, who gave the percentage of water under the same conditions as 1·54.

On a later page of the same volume,§ however, Fresenius, after a trial of the process which gave 99·66 per cent of the theory for copper, concludes that the method is practicable although apt to give low results, particularly in the presence of free acid.

The process was again recommended in 1878 by Busse,‖ who had employed it for the estimation of copper, both alone and in the presence of iron, nickel, zinc and arsenic, obtaining results very near the theory and plainly comparable with the figures obtained by afterwards igniting the cuprous sulphocyanide with sulphur in hydrogen.

In spite of the evident advantages for certain purposes of Rivot's method over other modes of determining copper, it has never come into general use. The chief reason for this has apparently been the difficulty and inaccuracy attendant upon the weighing of the precipitate upon dried paper filters, a process which can hardly be depended upon unless managed with extreme care.

* Comptes Rendus, xxxviii, 868.
‡ L. Gmelin Handb., iv, 472.
‖ Zeitschr. Anal. Chem., xvii, 53.
† Fresenius, 6th Aufl., i, 187.
§ 6th Aufl., i, 335.

In the experiments to be described this difficulty was avoided by performing the filtering and weighing upon asbestos in a perforated platinum crucible. The method of conducting a determination was as follows: A suitable quantity of a standard copper sulphate solution was run from a burette, diluted to a convenient volume, a few cubic centimeters of a saturated solution of ammonium bisulphite added, and the copper precipitated by an excess of ammonium sulphocyanide. The precipitate was allowed to settle, collected upon asbestos in a weighed crucible, washed with cold water and dried at 110° until no further loss of weight took place.

In Table I are given the results of a number of determinations made in this way. The copper sulphate solution was made up exactly decinormal and the standard confirmed electrolytically. As the ammonium sulphocyanide solution was slightly above decinormal, 13^{cm^3} represent a small excess (about one cubic centimeter) above the amount theoretically required to precipitate 25^{cm^3} of the copper sulphate solution. The ammonium bisulphite, which had been recently prepared by saturating aqueous ammonia with sulphur dioxide, was always used in sufficient quantity to give the liquid a strong and permanent odor of the latter.

TABLE I.

25^{cm^3} of N/10 $CuSO_4$ solution, equivalent to 0·0795 grm. Cu, taken for each experiment.

	H_2SO_4 concentrated. cm^3.	HNH_4SO_3 sat. sol. cm^3.	NH_4SCN approx. N/10. cm^3.	Final volume. cm^3.	Time of standing. hours.	Cu found. grm.	Error grm.
1.	none	5	13	68	¼	0·0795	0·0000
2.	"	3	13	66	48	0·0793	−0·0002
3.	"	3	25	78	½	0·0796	+0·0001
4.	"	3	25	78	12	0·0796	+0·0001
5.	1·5	10	13	85	12	0·0792	−0·0003
6.	1·5	8	13	105	48	0·0785	−0·0010
7.	1·5	3	25	85	4	0·0783	−0·0012
8.	1·5	5	25	85	21	0·0795	0·0000
9.	5	5	25	85	3	0·0797	+0·0002
10.	15	10	25	115	21	0·0793	−0·0002
	HCl concentrated cm^3.						
11.	10	5	25	100	20	0·0795	0·0000
12.	25	10	25	100	28	0·0784	−0·0011

When there is no free acid present the time of standing before filtration and the amount of the excess of ammonium sulphocyanide are practically without effect, as experiments 1 to 4 of the table show.

Experiments 5 to 10 were carried out in the presence of various amounts of free sulphuric acid up to 12 per cent of the total volume of liquid. The acid, at least within this limit, does not exert a sufficient solvent effect upon the cuprous sulphocyanide to interfere materially with the accuracy of the process, but it retards the precipitation, making it necessary to increase the time of standing before filtering in proportion to the amount of acid present. In several of these determinations the precipitation was visibly incomplete even after several hours standing. This effect of the acid, however, hardly shows in the results of the table because the standing was always prolonged until the copper appeared to be all down before filtering.

The low results of No. 7 was probably due chiefly to incomplete precipitation, although No. 9 shows that even with a much larger amount of acid precipitation may be complete within three hours. In general, however, it is safer to allow ample time (twelve hours or more) for the precipitation when there is much free acid present.

Comparison of Nos. 5 and 6, for which only a bare excess of ammonium sulphocyanide was used, with Nos. 7 to 12 shows an apparent advantage in the larger excess in the presence of acid. Hydrochloric acid, judging from the results of No. 11 and 12, has no greater disturbing influence than sulphuric acid, although in No. 12, where the concentrated acid constituted one-fourth of the entire volume, there was apparently a slight solvent action. The filtrate from this determination when concentrated to about 25$^{cm^3}$ and treated with potassium ferrocyanide gave a strong test for copper, as did also the filtrate from No. 6. Several of the other filtrates were tested in the same way, but none showed more than an insignificant trace of copper. No. 7, however, was not tested.

Table II contains the results of a series of experiments conducted as before, except that larger amounts of copper were

TABLE II.

	Cu taken. grm.	H_2SO_4 conc. cm^3.	NH_4SCN approx. N/10. cm^3.	Final volume. cm^3.	$Cu_2S_2(CN)_2$ found calc. as Cu. grm.	Error. grm.	Cu in filtrate.
1.	·3175	none	60	500	·3176	+0·0001	none
2.	·3175	"	60	500	·3177	+0·0002	"
3.	·3175	"	60	500	·3176	+0·0001	"
4.	·3175	10 HCl conc. cm^3.	100	500	·3175	0·0000	"
5.	·3175	20	100	500	·3165	−0·0010	distinct

employed. The copper sulphate solution was approximately N/5 and standardized by the battery. The solution of ammonium sulphocyanide was the same previously used and a considerable excess was employed in every determination. More than twice the amount theoretically required was used in every case where free acid was present, and at least twenty hours were allowed for the precipitation, which was made in cold, and as the table shows, rather dilute solutions. If the solution is too concentrated the copper is apt to be thrown down in a finely divided condition, making it hard to filter.

The time required to dry the cuprous sulphocyanide at 110° is in general from two to three hours. Heating much longer than this is not to be recommended, as a gradual increase in weight begins to take place, as is shown by the following example, which gives a series of weights of the same precipitate at different stages.

	$Cu_2S_2(CN)_2$. grm.	Calculated as Cu. grm.
After 2 hours at 110°	·6060	·3167
" 4 " " "	·6059	·3167
" 19 " " "	·6067	·3171
" 23 " " "	·6069	·3172

This tendency to increase in weight is, however, usually less marked than in the above example, and in any case need not interfere materially with the accuracy of the process unless the drying is prolonged far beyond the necessary length of time.

The method is easily handled and as the results of Tables I and II show is capable of considerable accuracy. From the nature of the process it is evident that it is much less likely to be interfered with by the presence of other metals than the other gravimetric methods for copper, and may therefore be directly applied with good results in many cases where the use of the electrolytic or the oxide method would involve a previous separation.

Silver Sulphocyanide.

The sulphocyanide of silver, unlike that of copper, is soluble in an excess of ammonium or alkali sulphocyanides and this fact prevents the use of the latter to precipitate silver for gravimetric estimation. The reverse process, however, the precipitation of a soluble sulphocyanide by an excess of silver nitrate, as will be shown by the experiments to be described, furnishes a convenient means of standardizing sulphocyanide solutions and in general for estimating thiocyanic acid.

When freshly precipitated the sulphocyanide of silver resembles the chloride in appearance, but when allowed to

stand a few hours becomes finely granular and is very easily filtered and washed. It may be safely dried to a constant weight upon an asbestos filter at 110°–120° but at a somewhat higher temperature is decomposed, leaving a residue of silver sulphide.

The determinations which are tabulated below were made as follows. Portions of 25$^{cm^3}$ of an approximately decinormal solution of ammonium sulphocyanide were measured from a burette, diluted with 100$^{cm^3}$ of water and silver nitrate added in excess. The precipitate was collected upon asbestos in a platinum crucible, washed with cold water and dried to a constant weight at 115° the drying requiring usually between two and three hours.

The filtering is facilitated by allowing a few hours for the precipitate to settle; but this is by no means essential, as it is easy with a little care to obtain a clear filtrate even when the filtering is performed at once.

The solution of ammonium sulphocyanide was prepared from a pure salt, especially tested and found free from choride. This point is of importance, as chlorine is a common impurity and its presence in any considerable quantity will vitiate the results.

TABLE III.

Final volume of liquid 150$^{cm^3}$

25$^{cm^3}$ of NH_4SCN sol. equivalent to 25·15$^{cm^3}$ of $AgNO_3$ sol.

	NH_4SCN cm^3	$AgNO_3$ cm^3	Excess of $AgNO_3$ cm^3	AgSCN found. grm.
1.	25	25·3	0·15	·4372
2.	25	25·3	0·15	·4376
3.	25	25·4	0·25	·4373
4.	25	25·4	0·25	·4375
5.	25	30·4	5·25	·4382
6.	25	Rough excess.		·4366
7.	25	"		·4381
8.	25	"		·4373
9.	25	"		·4372
10.	25	"		·4369

In order that the effect of varying the excess of silver might be investigated, an approximately decinormal solution of silver nitrate was titrated against the ammonium sulphocyanide and the ratio between the two solutions determined. This silver nitrate solution was used for the first five determinations of Table III. For the rest the quantity of silver nitrate was not measured but regulated by the eye alone, thus making

the conditions the same as would be the case in practical use of the method.

These results are as uniform as could be expected considering the variations which would be produced by even very small errors in measuring out 25^{cm^3} of decinormal sulphocyanide solution. It is moreover clearly shown that there is no difference in the results whether a bare excess or a moderately large excess of the silver nitrate is used.

The mean of the values in the last column is ·4374, which is equivalent to ·2006 grm. of ammonium sulphocyanide for every 25^{cm^3} of the solution.

The standard of the sulphocyanide solution was also determined volumetrically by Volhard's process. The mean of four titrations carried out with great care against a standard silver nitrate solution gave as the standard ·2003 grm of ammonium sulphocyanide for 25^{cm^3} of solution. This difference between the standards as determined by the two methods (one part in 670) is much less than the variations which frequently appear between successive determinations by Volhard's method, under like conditions as to strength of solutions and amounts used. It is about equal to the error that would be produced in a single volumetric determination by a mistake of one drop in measuring one of the solutions, or of one half drop in the same direction on each.

It is therefore evident that the standard of a sulphocyanide solution obtained in the above way may be applied directly to the estimation of unknown amounts of silver by Volhard's method without sensible error.

To remove a possible doubt as to whether the silver sulphocyanide dried at 115° was entirely free from water, a number of electrolytic determinations of the silver contained in the previously weighed precipitates of Table III were made in the following way.

The perforated platinum crucible containing the silver sulphocyanide and asbestos was hung in a loop of heavy platinum wire and served as the anode. For the cathode a deep platinum dish of about 200^{cm^3} capacity was used. An ammonical solution of potassium cyanide was employed as the electrolyte and gave the best results when made up by dissolving 2 grams of potassium cyanide in 15^{cm^3} of strong ammonia and 15^{cm^3} of water. The crucible which served as the anode was filled with this solution in full strength, and the remainder was put into the platinum dish and diluted to the required volume with water. In this medium the silver sulphocyanide is slowly dissolved and diffuses through the asbestos felt into the space between the electrodes where the silver is deposited in the usual way. This diffusion is, however, aided but little if at

all by the current, and there is a tendency for traces of the silver to remain behind in the crucible. The current density employed was about ·0012 ampére per square centimeter of cathode surface and the time about twelve hours. After weighing the silver deposited, it was dissolved in nitric acid, precipitated by hydrochloric acid and weighed again as the chloride, giving a check upon the results.

Seven of the ten determinations of Table III were thus treated, but owing to the imperfections of the process the results were all slightly low, the worst showing a deficiency of ·0025 grm. of silver, an error of less than 0·9 per cent. The results of the two best of these determinations given below are, however, sufficient to prove the point in question, namely that the silver sulphocyanide dried at 115° has the theoretical constitution and contains no water. The numbers are those under which the determinations appear in Table III.

	AgSCN taken grm.	Calc. as Ag. grm.	Ag found by battery. grm.	Error. grm.	Weighed as AgCl. grm.	Calc. as Ag. grm.	Error. grm.
4.	·4375	·2844	·2839	—0·0005	·3765	·2834	—0·0010
10.	·4369	·2840	·2838	—0·0002	·3761	·2831	—0·0009

It is clear therefore that the estimation of sulphocyanides by precipitation with silver nitrate and direct weighing of the precipitate is wholly permissible. The method is extremely simple and, as has been shown, the results are quite accurate.

In conclusion I wish to thank Prof. F. A. Gooch for many valuable suggestions given during the course of this investigation.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the action of Permanganate upon Hydrogen Peroxide.*—Several views have been advanced in explanation of this well known decomposition, in which the permanganate is decolorized and oxygen is evolved. Berthelot believes that a trioxide of hydrogen is produced which undergoes spontaneous decomposition into water and oxygen. This idea is based upon the fact that he produced the decomposition at $-12°$ without effervescence taking place. Schönbein's theory is that the two substances simultaneously give up atomic oxygen which condenses to the molecular condition. It is the view of Weltzien and Traube that permanganic acid oxidizes the hydrogen of hydrogen peroxide to water, thus liberating oxygen. According to the last explanation all of the evolved oxygen originates in the hydrogen peroxide.

Baeyer and Villiger have recently shown that the phenomenon observed by Berthelot was due to the supersaturation of the liquid by oxygen, and that if the liquid be gently agitated the evolution of gas takes place regularly. They observe that the hypothetical formation of hydrogen trioxide is an assumption which is supported by the formation of potassium polysulphide when sulphur and potassium sulphide are brought together, and also by the formation of potassium tri- or tetra-oxide, as observed by Schöne, when a solution of hydrogen peroxide is evaporated with potash; but the assumption now lacks foundation in fact. According to Schönbein's theory both substances act as oxidizing agents. The authors believe, however, that hydrogen peroxide is hardly to be considered as such an agent, since in the pure condition it decomposes dilute hydriodic acid only very slowly. Moreover, if the theory is true, the more strongly oxidizing derivatives of hydrogen peroxide should oxidize permanganate still more easily and evolve oxygen, while in fact exactly the opposite is the case, for example, with "Caro's acid" which does not attack permanganate. This view, therefore, is not supported by facts. The authors strongly favor the view of Weltzien and Traube that it is the hydrogen of the hydrogen peroxide that is oxidized to water. Hydrogen peroxide thus shows a behavior analogous to that of hydrogen sulphide, with which it shows a striking similarity in many other ways. They urge the adoption of this theory, agreeing as it does with the present state of our knowledge, by the authors of elementary text-books.—*Berichte*, xxxiii, 2488. H. L. W.

2. *An Instance of Trivalent Carbon: Triphenylmethyl.*—In a preliminary paper Gomberg describes a body produced by the action of zinc upon triphenylchlormethane, $(C_6H_5)_3C\,Cl$, which is an unsaturated compound apparently containing but one carbon atom and corresponding to the formula $(C_6H_5)_3C$. The substance

combines with atmospheric oxygen with great readiness, forming di-triphenylmethylperoxide $(C_6H_5)_3C.O_2.C(C_6H_5)_3$. This property renders the preparation of the unsaturated hydrocarbon in the pure state extremely difficult, and although the author has succeeded in obtaining large crystals of it, he has not yet been able to wash them without the formation of the peroxide. If subsequent investigation confirms the preliminary conclusions, the compound will possess great theoretical interest as being the first unsaturated compound of the kind, and furnishing the first definite evidence of the existence of the trivalent carbon atom.—*Jour. Am. Chem. Soc.*, xxii, 757. H. L. W.

3. *On the Phosphorescence of Inorganic Chemical Preparations.*—This subject has been studied by E. GOLDSTEIN. The method of investigation consisted in placing the substance under examination in a properly shaped tube and waving the latter back and forth in a cone of cathode rays. The nature of the phosphorescence could be determined from the length of the observed trail of light. The examination of various pure samples of a substance showed that the color of light attributed to it by previous investigators becomes weaker as the substance becomes purer. On the contrary, the light which appears at the point of contact with the cathode rays, and which lasts only during the illumination, becomes continually brighter as the purity increases. The substances investigated may be divided into two groups in respect to their phosphorescent light. In the case of the sulphates, carbonates, phosphates, borates, silicates, chlorides, bromides, fluorides, oxides, and hydroxides of Li, Na, K, Rb, Cs, Ca, Sr, Ba, Al, Zr, Mg, Be, Zn, and Cd the color is blue, violet-blue, or in a few instances violet. Salts of Cu, Cr. Mn, U, Ni, Co, Pb, Ce, La, Y, Er, Pr, and Ne belong to the other group. The latter, when admixed in very small amounts with compounds of the first group, give a light which in most cases exceeds the blue light in intensity and duration, but corresponding phenomena could not be observed when reciprocal additions from the first group were made. There is a maximum in the strength of the colored light, for it decreases again when the small amount of substance from group 2 is increased beyond a certain limit. The presence of moisture may possibly be assigned as the reason for the similar luminosity of the substances of the first group. The effect of additions from the second group may possibly be due to greater power of absorption or else to the occurrence of decomposition.—*Chem. Centrál-Blatt*, 1900, ii, 756. H. L. W.

4. *Weight of Hydrogen Desiccated by Liquid Air.*—LORD RAYLEIGH has found that the density of hydrogen dried by cooling with liquid air is the same as that obtained when the gas is dried with phosphorus pentoxide. This was to be expected, for it was shown by Morley in an article published in this Journal in September, 1887, that this oxide is a practically perfect dryer for gases, but it is satisfactory to have a confirmation of this important fact.—*Proc. Roy. Soc.*, lxvi, 334. H. L. W.

5. *The Separation of Tungsten Trioxide from Molybdenum Trioxide.*—M. J. RUEGENBERG and EDGAR F. SMITH describe a method of separation for the oxides mentioned in the title. It is based upon the fact that tungstic acid is insoluble in concentrated or dilute sulphuric acid, hot or cold, whereas molybdenum trioxide is very easily and rapidly dissolved. Upon trial it was found that sulphuric acid of specific gravity 1·378 was well suited for the purpose. Test analyses were made by mixing about 1 or 2 grams of molybdic anhydride with varying quantities of tungstic anhydride and digesting with 25^{cc} of warm sulphuric acid of the strength mentioned above for a few minutes, then filtering, washing with water containing sulphuric acid, and weighing the tungstic acid. The results of six analyses were extremely sharp. The authors found also that tungstic acid may be separated from ferric hydroxide in precisely the same way.—*Jour. Am. Chem. Soc.*, xxii, 772. H. L. W.

6. *On Radio-active Barium and Polonium.*—When concentrated uranium nitrate solution is mixed with a little sulphuric acid, then with a solution of a barium salt, care being taken that sufficient barium salt is not added to cause a precipitate, and finally diluted with water, a strongly radio-active precipitate of barium sulphate is obtained. When this sulphate is converted into a soluble barium salt and this is treated with ammonium hydroxide, a small amount of precipitate is obtained which is even more strongly radio-active than the original sulphate; but when the barium is subsequently converted into carbonate, it has completely lost its activity. The radio-activity is probably due to small quantities of radium, or more probably of actinium. Polonium preparations obtained from lead chloride from uranium residues have proved to consist of bismuth hydroxide, which, either in this form or as oxychlorides exhibits strong activity.—*Berichte*, xxxiii, 1665. *Jour. Chem. Soc.*, lxxviii, 480.

7. *Lecture Experiments Illustrating the Electrolytic Dissociation Theory and the Laws of the Velocity and Equilibrium of Chemical Change.*—A. A. NOYES and A. A. BLANCHARD have published a description of seventeen experiments which were originally devised as an accompaniment to an extended course of lectures on theoretical chemistry. Most of the principles illustrated are of such fundamental importance that they should soon be generally introduced into elementary lecture courses on inorganic and analytical chemistry. The experiments are devised with much skill and will furnish very striking illustrations to the audience. They are described in great detail, so that they may be readily performed by the lecturer, and the principles illustrated are clearly stated in each case. It is certain that this series of experiments will be of great assistance to teachers of theoretical chemistry, and it will doubtless serve to hasten the introduction of instruction in the principles of chemical equilibrium and of electrolytic dissociation into elementary courses.—*Jour. Am. Chem. Soc.*, xxii, 726. H. L. W.

8. *Physikalisch-chemische Propädeutik;* von H. GRIESBACH, zweite Hälfte, 3 Lieferung, Band I, pp. 945–992 and Band II, pp. 1–352. Leipsic, 1900 (Wilhelm Engelmann). The first two installments of this work were noticed in this Journal, December, 1896. The present, fourth installment gives a most favorable impression of the author's success in continuing the excellence of his work. The size of the book as well as its scope have been enlarged beyond the original intention, so that a second volume is now begun. In giving a general view of modern scientific knowledge the work will be valuable to many classes of readers.

H. L. W.

9. *A School Chemistry;* by JOHN WADDELL. 12mo, pp. xiii, 278. New York, 1900 (The Macmillan Company).—This text-book on elementary chemistry possesses many excellent features. The author has shown much originality in his presentation of the subject, good judgment in regard to the scope of the book, and accuracy in his statements of facts and theories. The interrogatory method is largely employed with the object of stimulating the pupil's thought. It is the aim of the book to help the student in the discovery of facts, to enable him to see their connections, and to show how facts lead to theory. H. L. W.

10. *Leçons de Chimie Physique;* by J. H. VAN'T HOFF. Volume III. Relations between the properties and the composition. Translated from the German edition by M. Corvisy. 8vo, pp. 170, Paris, 1900 (A. Hermann).—This book is a very literal translation of the concluding volume of van't Hoff's "Vorlesungen über Chemie" which appeared early in the year. The subject treated is, however, practically independent of the two earlier volumes. The relations between the physical properties and the composition are first taken up. Under this heading, come the relations and behavior of matter in regard to space, pressure, temperature, heat, surface tension and optical properties. The second half of the book treats of the relations between the chemical properties and the composition.

Van't Hoff has made a wide departure from other books on physical chemistry which have thus far appeared. He aims not to treat the subject exhaustively but to take up the more important or more interesting parts, and these are treated in his usual brilliant manner. H. W. F.

11. *On the Viscosity of Gases as affected by Temperature;* by Lord RAYLEIGH.—A former paper* describes the apparatus by which I examined the influence of temperature upon the viscosity of argon and other gases. I have recently had the opportunity of testing, in the same way, an interesting sample of gas prepared by Professor Dewar, being the residue, uncondensed by *liquid hydrogen*, from a large quantity collected at the Bath springs. As was to be expected, it consists mainly of helium, as is evidenced by its spectrum when rendered luminous in a vacuum tube. A line, not visible from another helium tube, approximately in the position of D_3 (Neon) is also apparent. The result

* This Journal, ix, 365.

of the comparison of viscosities at about 100° C. and at the temperature of the room was to show that the temperature effect was the same as for *hydrogen*.

In the former paper the results were reduced so as to show to what power (n) of the absolute temperature the viscosity was proportional.

	n	c
Air	0·754	111·3
Oxygen	0·782	128·2
Hydrogen, Helium	0·681	72·2
Argon	0·815	150·2

Since practically only two points on the temperature curve were examined, the numbers obtained were of course of no avail to determine whether or no any power of the temperature was adequate to represent the complete curve. The question of the dependence of viscosity upon temperature has been studied by Sutherland, on the basis of a theoretical argument which, if not absolutely rigorous, is still entitled to considerable weight. He deduces from a special form of the kinetic theory as the function of temperature to which the viscosity is proportional

$$\frac{\theta^{\frac{1}{2}}}{1+c/\theta}$$

c being some constant proper to the particular gas. The simple law $\theta^{\frac{1}{2}}$, appropriate to "hard spheres," here appears as the limiting form when θ is very great. In this case, the collisions are sensibly uninfluenced by the molecular forces which may act at distances exceeding that of impact. When, on the other hand, the temperature and the molecular velocities are lower, the mutual attraction of molecules which pass near one another increases the number of collisions, much as if the diameter of the spheres was increased. Sutherland finds a very good agreement between his formula (1) and the observations of Holman and others upon various gases.

If the law be assumed, my observations suffice to determine the values of c. They are shown in the table, and they agree well with the numbers for air and oxygen calculated by Sutherland from observations of Obermayer.—*Proc. Roy. Soc.*, lxxvii, 137.

12. *Absorption of gases by glass powder.*—Early investigators claimed that the absorption of gases ceased in a few days; that it increased with increasing pressure; diminished with increasing temperature; and that the presence of moisture had little influence. Bunsen on the other hand found that the absorption continued even for years; increased with increasing temperature, and was largely independent of variations of pressure. The cause of the absorption he claimed to be in the capillary coating of moisture. P. Mülfarth (Bonn dissertation) gives an exhaus-

tive list of references of work upon this subject. His conclusions vary from those of the previous investigators.

Fully dried glass powder absorbs a large amount of CO_2. The amount increases with diminishing temperature and rises with increasing temperature: it is accomplished in a few hours. The presence of moisture hinders this absorption. The absorption of SO_2 is similar to that of CO_2: it is accomplished in a couple of hours—increases with increasing pressure, diminishes with increasing temperature. The following absorb in the order written: C_2H_2, N_2O, CO_2,SO_2,NH_3. The investigation bears upon the preparation of X-ray tubes, and also upon the question of the influence of the glass walls of vessels in spectrum tubes.—*Ann. der Physik*, No. 10, 1900, pp. 328–352. J. T.

13. *Normal lines of iron.*—Rowland has published a list of iron lines which serve for normals in spectra comparisons. KAYSER finds that this list is not sufficient for certain regions of the solar spectrum, and, therefore, has given a large additional number between wave lengths 2300 and 4500. The author claims a higher accuracy than that reached by Rowland since every wave length in his table is the mean of from 6–15 measures, taken with gratings of different orders. The probable error lies between 0·001 and 0·003.—*Ann. der Physik*, No. 10, 1900, pp. 195–203. J. T.

14. *Arc spectra of some metals in an atmosphere of hydrogen.*—HENRY CREW finds that a hydrogen atmosphere profoundly modifies certain arc spectra of metals, and that all the lines in the arc spectra which are affected by hydrogen belong to the spark spectrum also. Moreover that the lines which belong to Kayser and Runge's series are unaffected by the change from air to hydrogen. —*Phil. Mag.*, Nov., 1900, pp. 497–505. J. T.

15. *Recognition of the Solar Corona independent of the total eclipse.*—H. DESLANDRES has made some observations at Meudon which apparently show the possibility of observing the corona under ordinary conditions by the aid of a thermopile.—*Comptes Rendus*, Oct. 22, 1900. J. T.

16. *Loss of charge by evaporation.*—Various physicists have arrived at different conclusions on this subject. W. CRAIG HENDERSON, working in the Cavendish laboratory, has investigated the subject anew and comes to the conclusion that there is no appreciable loss of charge by the evaporation of a charged liquid.—*Phil. Mag.*, Nov., 1900, pp. 489–497. J. T.

17. *On the action of the coherer.*—Previous investigations seem to show that the action of the coherer is due to the welding action of minute sparks in the powders which are employed. T. MIZUNO of Kyoto University has studied the behavior of a large number of substances. He finds that the action of the iron powder coherer is conspicuously irregular and concludes that the action of the coherer can plausibly be explained on the hypothesis of the welding action of minute sparks.—*Phil. Mag.*, Nov., 1900, pp. 445–459. J. T.

18. *Loss of electrical charges in air which is traversed by ultra-violet rays.*—P. LENARD published a paper on the effect of ultra-violet rays on gas in the Annalen der Physik, No. 1, 1900, p. 486. He now continues his investigation and shows that the effect of ultra-violet light is fourfold. The air is divided into bearers of negative electricity which appear to be charged atoms or molecules; bearers of positive electricity of larger dimensions; nuclei of vapor which are non-electrified; and ozone.—*Ann. der Physik*, No. 10, 1900, pp. 298–319. J. T.

19. *Handbuch der Spectroscopie* von H. KAYSER. Erster Band. Pp. xxiv, 781; large 8vo; 781 figures in the text. Leipzig, 1900 (S. Hirzel).—The preparation of a comprehensive work on a subject which has had so remarkable a development as that of spectroscopy in its different branches, is a labor of such magnitude that we may well honor the energy of the author who ventures to undertake it. But here we have not simply the promise but also its fulfilment in the completion of a considerable part of the undertaking. The present volume of nearly eight hundred pages by Professor Kayser, is so thorough and so satisfactory a treatment of the portions of the subject here included, that the reader feels justified in looking forward with confidence to the completion of the remaining four volumes promised as a well-rounded whole.

The volume opens with an admirable summary, scientific and yet thoroughly readable, of the history of spectroscopy from the time of Newton down to the present. Although an exhaustive treatment of this subject might well extend the chapter to the limits of a volume by itself, the author presents the salient points in the successive steps of progress, and the contributions of each worker so clearly, that the chapter as a whole leaves little to be desired. In the treatment of the delicate question of the claims of earlier writers to the discoveries which are usually connected with the name of some physicist who has come later, the author shows much discrimination and critical care; for example in regard to the relative amount of credit to be given to Wollaston as contrasted with Fraunhofer, or to Talbot, Miller and Stokes as compared with Kirchhoff. The same critical method appears throughout. The five other chapters of the volume deal with the practical working of spectroscopy. The first of these discusses the production of incandescent vapors in the flame, arc-light, or vacuum tubes. This subject is treated both historically with a multitude of references to original authorities and descriptively as needed by a present worker. The two chapters following discuss prisms and diffraction gratings, giving the theory, construction and use in detail. In the former subject the author has been aided by Dr. H. Konen, while Prof. C. Runge has furnished for the volume his theory of concave gratings. The concluding chapters are devoted to spectroscopic apparatus and measurements, the use of photography and other methods. Here, as throughout the volume, we are struck with the simplicity and

directness of statement, and the thoroughness with which the work of the many physicists who have contributed is recognized. Even where only a very brief allusion is possible to some matters of minor importance, they are not ignored, but the literature references at the bottom of each page embrace all that has been done on the subject. The great steps of progress that have been made, as the Rowland grating, the methods for the investigation of the infra-red spectrum by Abney, the echelon spectroscope of Michelson, are treated with all necessary fullness.

The second volume is to be devoted to Kirchhoff's law and its consequences, emission spectra of different kinds and as obtained under varying conditions of pressure, temperature, magnetic force, etc. The third volume will include the absorption phenomena with also fluorescence and phosphorescence; the fourth volume will give all spectroscopic data available in regard to each individual element, and a fifth is also planned to include the spectroscopy of the heavenly bodies including the Sun.

20. *A Brief Course in General Physics, experimental and applied;* by GEORGE A. HOADLEY, Swarthmore College. Pp. 463, New York, 1900 (The American Book Company).—This is a clear, systematic statement of the fundamental principles and laws of physics, such as is needed by the high school student; it is accompanied by good illustrations and a well-chosen series of experiments. The subjects in general are well treated, although at occasional points open to criticism; thus we find in one article a brief statement of surface tension and in one following, an explanation of capillary attraction, but there is no suggestion as to any connection between the two subjects.

II. GEOLOGY AND MINERALOGY.

1. *U. S. Geological Survey, 20th Annual Report 1898–99. Part III. Precious Metal Mining Districts.* (Washington, 1900, pp. 595, pls. 77.)—This volume consists of three papers, two of them having appended reports by specialists.

I, *A preliminary report on the Bohemia mining region of western Oregon*, with notes on the Blue River mining region and on the structure and age of the Cascade range by J. S. DILLER, which is accompanied by a report on the fossil plants associated with the lavas of the Cascade range by F. H. KNOWLTON (pp. 1–64, pls. 1–6). The brief sketch of the district shows that the rocks of Calapooya Mountain, upon which the district lies, are wholly of igneous origin. They consist of dacite porphyry, andesites and basalts with volcanic tuffs. It is in these rocks that the mines are situated which are described in the report. The veins are gold-bearing. The fossil plants found in the tuffs show that the latter were deposited in lakes of Miocene age. The various localities from which fossil leaves have been collected are mentioned and in his special report Knowlton describes

these leaves, showing them to represent a flora of Miocene age made up of conifers, oaks, etc., and including several new species.

II, *Gold and silver veins of Silver City, De Lamar and other mining districts in Idaho*, by W. LINDGREN (pp. 65–256, pls. 7–35). This begins with a sketch of the general geology of western central Idaho, accompanied by a geologic map, based in part on actual surveys made by the author and in part on reconnaissance work. The map shows a central area of post-Carboniferous granite of great size, bordered on the east by Carboniferous beds in which it has produced contact metamorphism. The Snake River runs through the southern and, turning to the north, the western portions of the area and along its course is bordered by immense outflows of basalts, some of Miocene, others of Pliocene age. The Silver City and De Lamar district is in this southern part on a granite ridge which rises above the flood of basalt and rhyolite. The gold and silver veins of this district, their mode of occurrence, the associated minerals, the individual mines, etc., are carefully and fully described. In the same manner the author gives an account of the Wood River district, where the silver-lead ores occur in veins cutting the Carboniferous beds. At Florence and Warren, situated in the great granite area, the veins are gold quartz and some placer mining is done. In the Seven Devils district the ore is copper in the contact zone of the granite mass with the Carboniferous beds on its western side. The ores are bornite and chalcopyrite and are supposed to have been deposited by pneumatolytic processes. The paper contains a wealth of careful observations on a large number of ore deposits and is a most important contribution to the study of ore deposits in general.

III, *Geology of the Little Belt Mountains of Montana*, with notes on the mineral deposits of the Neihart, Barker, Yogo and other districts by W. H. WEED, with a report on the petrography of the igneous rocks of the district by L. V. PIRSSON.

The Little Belt Mountains are an anticlinal uplift of a rather broad, even character. In the central portion erosion has disclosed the fundamental Archean gneisses and schists upon which the later sediments lie. These range through the Belt formation (here having a considerable local development and supposed to be of Algonkian age), the Cambrian, Siluro-Devonian, Carboniferous, up to the Cretaceous forming the outer foot hills, slopes and boundary plains of the area. The streams rising in basins of Belt or Cambrian shales pass through deep and narrow canyons or gateways of Carboniferous limestone. Chiefly on the outer margin of the range, along the spring of the arch, great laccolithic intrusions of igneous material have taken place, which now present either wholly or partly uncovered masses of porphyries of several types. Accompanying them are numbers of intruded sheets and dikes.

The basins cut in shale, the flat-topped plateaux of limestone, the deep gorges cut on the outer flanks of the range and the

great mountains of igneous rock form the dominating features of topographic relief and express the geologic relations. The formations are described and also the local geology of the various districts is given in detail and several features of general interest in structural and dynamical geology, particularly with reference to the intrusion of laccoliths are brought out.

The ores are found chiefly in two districts; at Barker where they are of the type of silver-lead ores occurring in limestones at the contact of intrusive igneous masses, and at Neihart where intrusions of diorite and other rocks have occurred in the Archean complex. At this place the ores occur in a well defined vein system and are gold and silver, the latter occurring in the sulphides, ruby silver, polybasite, etc. The important mines, their ores and workings are described.

The petrographical report contains a full description of the igneous rocks which are chiefly porphyries of several kinds, granite, syenite and diorite porphyries with intermediate types. At Yogo peak is a differentiated mass changing from granite porphyry through monzonites to shonkinite. The intruded sheets and dikes present several rock varieties, the most interesting of which are the minettes and analcite basalts. Of all these types detailed analyses by W. F. Hillebrand and H. N. Stokes are given and in the theoretical discussion of the rocks of the district are used to show that all of the main types are so related to one another in a rock series that any one of them may be expressed in terms of the others; these relations being shown by a diagram in graphic form. L. V. P.

2. *Iowa Geological Survey, Vol. X. Annual Report, 1899, with accompanying papers.* Samuel Calvin, State Geologist, H. F. Bain, Assistant State Geologist. Pp. 1–166, plates i–xi, figures 1–102, and 10 folded maps, 1900.—The Geological Board of the State of Iowa is to be congratulated both upon the admirable organization of its geological workers and upon the equally admirable results it is annually producing. The board is constituted of the governor, the auditor of State, two college presidents and the president of the Iowa Academy of Sciences, thus combining for effective service the forces of politics, education and science. The geological staff for the year, besides the geologist and assistant geologist, is drawn from the officers of six of the colleges of the State and one high school and one from the Chicago University. The papers of the present volume are chiefly connected with the detailed mapping of the geology of counties not previously so mapped. Forty-two counties in all have been mapped, eight of them having been completed within the year. The great value of the topographical sheets prepared by the U. S. Geological Survey is acknowledged, particularly in respect to the Dubuque region, the important lead mines of which are scientifically described in the chapter on Dubuque County, prepared by the geologist and assistant geologist.

Mr. Frank Wilder brings to notice, the fact "that the Hawarden

beds, heretofore referred to the Ft. Pierre, really belong to the Benton shales and accordingly the limestones and chalk of the Inoceramus beds, as developed in Iowa, are not to be correlated with the Niobrara farther west. They represent instead that portion of the Fort Benton sub-stage exposed in the 'Oyster Shell Rim' of the Black Hills." The principle of coöperation expressed in the organization of the survey, is further carried out in the formation of a joint commission to investigate the clay resources of the State. This commission is composed of the Iowa Brick and Tile Makers' Association, Iowa Engineering Society, the State College, and the State University. The results of their work during the year is given in Dr. Beyer's appended report on the Mineral Production of Iowa, in 1899. H. S. W.

3. *Cleopatra's Emerald Mines.*—An account is given in the November number of the Geological Journal of an expedition led by Mr. DONALD A. MAC ALISTER to the so-called Cleopatra's Emerald Mines in the neighborhood of Jebel Sikait in Northern Etbai. The locality is situated nearly due east of Edfu, and some fifteen miles in a direct line from the Red Sea, between 25° and 24° 30′ N. Lat. The place was reached by the expedition starting from Daraw. The mountain, Jebel Sikait, has an altitude of 1800 feet above sea-level and commands an extensive view over the wild and desolate surrounding country.

The emeralds occur in mica schist and talc schist, which rocks occur over a large area. The mica schist is in some cases highly micaceous, looking like a finely bedded, contorted sandstone, and again contains very little quartz. In some cases the rock is much hydrated, passing into a soft, powdery rock. Tourmaline, garnet, actinolite, chrysolite are common minerals of the locality. The schists of Jebel Sikait are inclined at an angle of about 45°, and overlie gneiss on one side, while on the other they are inclosed by a tough, green serpentine, of which the upper part of the mountain is composed. The search for emeralds was carried on two thousand years ago very extensively, a large number of mines being opened and extensive workings being carried forward. The author remarks in regard to this subject:

"The mining is of a most primitive character. The ancients simply excavated, in the likely emerald-bearing schist, a network of long and very tortuous passages just large enough to allow of the body being dragged through, and only in a very few cases was any attempt made at stopping (or excavating) the entire seam. It has been suggested that the passages were made small on account of the absence of timber, suitable to be hewn into supports, which would be necessary to prevent collapses in the case of larger excavations. So small are the openings, that a casual observer would not notice the existence of a mine at all but for the gray *débris* thrown out at the mouth. Along the schists at Sikait alone we visited considerably over a hundred mines, some of which took more than an hour to crawl through. That these mines have been worked at widely distant periods, is

evident from the different styles of work. There are seven or eight groups of mines in different places within a couple of hours or so of Jebel Sikait."

4. *Handbuch der Mineralogie*, von Dr. CARL HINTZE. Erster Band, fünfte Lieferung; pp. 641–800. Leipzig, 1900 (Veit & Company).—The fifth part of the first volume of Hintze's Mineralogy (No. 17 of the entire series) has recently been issued. It contains the closing pages in regard to the pyrrhotite group, descriptions of the species of the cinnabar group, and the opening portion of the pyrite group. The treatment is as thorough and exhaustive as that which has characterized the parts already published.

5. *Contributions to Chemistry and Mineralogy from the Laboratory of the U. S. Geological Survey*, F. W. CLARKE, Chief Chemist. Pp. 166, Washington, 1900. (Bulletin 167, U. S. G. Surv.)—This Bulletin, like others which have preceded it from the same source, contains a series of chemical and mineralogical researches carried on in the laboratory under the charge of Prof. Clarke. Several of the papers included, as that on the constitution of tourmaline, and others, have already been published in part or entire in this Journal. Among others may be mentioned a series of papers by H. N. Stokes on the chloronitrides of phosphorus and the metaphosphimic acids.

6. *Johnstonotite, a supposed new Garnet.*—W. A. MACLEOD and O. E. WHITE have given the name johnstonotite (after R. M. Johnston) to a brownish-yellow garnet occurring in trapezohedral crystals in trachyte at Port Cygnet, Tasmania. An analysis gave:

SiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Ign.
36·87	7·28	17·12	13·68	12·49	11·98	0·29 = 99·71

It would seem to be analogous to the spessartite of Colorado, which is similar in occurrence; however, although regarded as differing from other garnets in the relative proportions of the bases, the analysis cannot be accepted as accurate since (as noted by the reviewer, L. J. Spencer) the formula only approximates to that of garnet, even if all the iron is made Fe_2O_3.—*Proc. R. Soc. Tasmania*, 1898–99, 1900, 74, noticed in *J. Chem. Soc.*, lxxviii, 663.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures and condition of the Institution for the Year ending June* 30, 1898. Pp. lv, 713. Washington, 1899.—The report of the Secretary of the Smithsonian Institution, Prof. S. P. LANGLEY, which has just been issued, contains the usual interesting summary of the recent progress of the Institution in its various departments of research and exploration, collections, library and publications, and foreign

exchange. The growth in the *National Zoological Park* is noted in particular and also the results obtained in the *Astrophysical Observatory* by Mr. C. G. Abbott, the Aid in charge. Professor Langley states that the work of the last year "has resulted in the discovery and determination of position of 500 new absorption lines, so that we have now over 700 new lines of well-determined positions, and we may be said now to know, by the aid of the bolometer and the labors of the observatory, more lines in this invisible spectrum than were known in the visible one up to the great research of Kirchhoff and Bunsen, which opened the era of modern spectrum analysis. Moreover, these lines, the exactness of whose determination has now reached a surprising degree of perfection through the recent improvements in the delicacy as well as the precision of both bolometer and galvanometer, and through other improvements in the apparatus (improvements due principally to the present Aid acting in charge), depend not only on the instruments, but on the labors of those who have used them, the comparator measurements alone having included, as stated in the body of the report, about 44,000 separate observations.

"A great deal of other work has been done at the observatory, but nothing which in importance and present and prospective interest compares with this main research in the infra-red spectrum, which is now known throughout nearly the whole of the invisible portion of the solar energy, and extends through a range of wave lengths considerably over twelve times that known to Sir Isaac Newton, the present exact knowledge of this region being due not exclusively, but it may properly be said principally, to the labors of this observatory.

"I call attention in this connection to the interesting remarks made in the report to the effect that very marked changes of absorption have been observed at various parts of the infra-red spectrum. In one part of the invisible region a decrease in absorption, amounting to nearly half the total, took place in February, and this abnormal state continued until May, when the usual condition gradually returned. As this change is found to occur yearly at about the same period, the idea presents itself that the growth of vegetation, so rapid in these months, may abstract from the air large quantities of vapor active in absorption at this point in the spectrum, but this interesting possibility has not yet, it will be understood, been fully verified."

The second part of the volume, pp. 101–696, contains a series of well-selected papers on important topics, many of them not readily accessible in the original, so that their republication here will be a great convenience to many readers.

2. *Report of the U. S. National Museum under the direction of the Smithsonian Institution for the year ending June 30, 1898.* Pp. xviii, 1270; plates 1–36. Washington, 1900.—This volume contains the report by the Director, Mr. Charles D. Walcott, on the condition and progress of the United States National Museum

during the year ending June 30th, 1898; also the reports of the head curators, W. H. Holmes in Anthropology, F. W. True in Biology, and G. P. Merrill in Geology; further lists of accessions to the collections and library (pp. 1–152). Part II, following, is given to an extended paper by the late Professor E. D. Cope, on the Crocodilians, Lizards, and Snakes; this covers pages 153 to 1270, with thirty-six plates and numerous text figures.

The Director, in his brief statement, shows the remarkable growth which the Museum has made and emphasizes the imperative need of a larger, more dignified and more convenient building, not simply for exhibition purposes, but also to include laboratories and a lecture hall. He shows further the directions in which it is to be desired that the National Museum should develop in the immediate future, and the great service which it may thus do to the country at large. It is greatly to be hoped that his appeal may be regarded and adequate provision made, not only for the present needs of the Museum but also for its future growth.

3. *Publications of the Earthquake Investigation Committee in Foreign Languages.* Tokyo, 1900. No. 3, pp. 1–103. No. 4, pp. 1–141.—These publications of the Japan Earthquake Committee contain a series of papers of much interest to seismologists, chiefly in English, in part also in French. Among these are accounts, with seismical records, of several destructive earthquakes (1891–1894). A paper of general interest is by H. NAGAOKA, on *the elastic constants of rocks and the velocity of seismic waves.* This gives a long series of observations on specimens of rocks from Archean chlorite schist, through the Paleozoic to quartz-sandstones and andesites of the Tertiary. The modulus of elasticity, and modulus of rigidity were determined in each case, as also the density, and from these data the corresponding velocities for elastic waves were then calculated. The author finds a distinct gradation in the elastic constants from the higher values characteristic of the oldest rocks down to those of the youngest; the velocity of wave-propagation is not, however, proportionally larger, since the density also enters into the problem. Thus for an Archean chlorite schist a velocity of 6·4 to 7 kilometers per second is obtained for longitudinal waves; for a Paleozoic clay slate a velocity of 4·5 to 6; while for a Tertiary sandstone the value is only 2·2. The experiments made seem to show that the elastic constants increase more rapidly than the density as the rocks become more dense, and consequently elastic waves travel with greater velocity in the interior than on the surface of the earth's crust. Eruptive rocks are more isotropic than those of non-igneous origin and have inferior elasticity, but there is with them also the same distinction as to age. The schistose structure of the deeper rocks gives a greater value of the elastic constants in a certain particular direction, coinciding with that of swiftest propagation of elastic disturbances. It seems to be shown that the ratio of elastic constants to density, and hence

the velocity of elastic waves, increases from the surface downward to *a stratum of maximum velocity*, probably at a considerable depth, and then diminishes again. The conclusion of Professor Omori from records in Italy and Japan, that the velocity of the first tremor is almost always equal to 13 kilometers per second, while longitudinal waves in steel have only a velocity of 6·2, is difficult to account for; it may be explained by the probable supposition that the rocks deeper in the earth's crust have elastic constants several times greater than those near the surface. The velocity named would roughly correspond to the values $E = 6 \times 10^{12}$ and $\rho = 3{\cdot}5$. The high value of the elastic constant relative to the density is not impossible, since, in passing from Tertiary to Archean rocks an increase of density from 2 to 3 is here shown to be accompanied by an increase of the modulus of elasticity more than ten times in some cases.

4. *The Graduate Bulletin of the University of Nebraska.* Volume I, No. 1, pp. 1–68. Lincoln, Nebraska, 1900.—Among the papers here published is one by E. J. Rendtorff, on acromatic polarization with crystalline plates; another by C. C. Engberg on the Cartesian oval, and one by C. A. Fisher on the geology of Lincoln and environs.

5. *National Academy of Sciences.*—The autumn meeting of the National Academy was held at Providence, Nov. 13–15th. The following is a list of the papers read (several by title):

J. TROWBRIDGE: Investigations of light and electricity with the aid of a battery of twenty thousand cells.

ALPHEUS HYATT: Progressive evolution of characters in the young stages of Cephalopods. Descriptive method of presenting the phenomena of the cycle of evolution among Cephalopods.

T. W. RICHARDS: The porous cup voltameter. An account of the study of growing crystals by instantaneous microphotography.

S. L. PENFIELD: Stereographic projection and some of its possibilities from a graphical standpoint.

C. S. MINOT: On the development of the pig. Normal plates illustrating the development of the rabbit and the dogfish.

T. C. MENDENHALL: Note on the energy of recent earthquakes.

A. A. MICHELSON: Spectrum of sodium in a magnetic field. Progress in the Echelon spectroscope.

H. A. ROWLAND: A report of the spectrum work carried on with the aid of a grant from the Bache Fund. On the explanation of inertia and gravitation by means of electrical phenomena.

A. S PACKARD: Distribution of philogeny of Limulus. Male preponderance (androrhopy) in Lepidopterous insects.

A. MICHAEL: The synthesis and reactions of sodium acetate ester, and their relation to a new interpretation of chemical metathesis. On the genesis of matter

C. BARUS: Demonstration of the projection of one grating by another. Exhibition of certain novel apparatus: A wave machine; an expansion lens; a recording system of two degrees of freedom; A tube showing colored cloudy condensation On stability of vibration and on vanishing resonance. Hysteresis-like phenomena in torsional magnetostriction and their relation to viscosity.

CHARLES D. WALCOTT: Folding and faulting of strata in the Cordilleran Area.

J. M CRAFTS: Report on the Meeting of the Committee of the International Association of Academies held at Paris.

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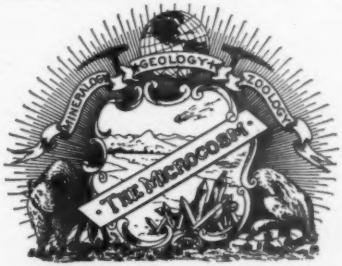

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(1) Described in this Journal Sept., 1895. (2) Ibid Nov., 1887. (3) Proc. Roch. Acad. Sci. Vol. I. (4) This Journal Aug., 1888. (5) Ibid July, 1893. (6) Ibid June, 1894. (7) Ibid Nov., 1892.

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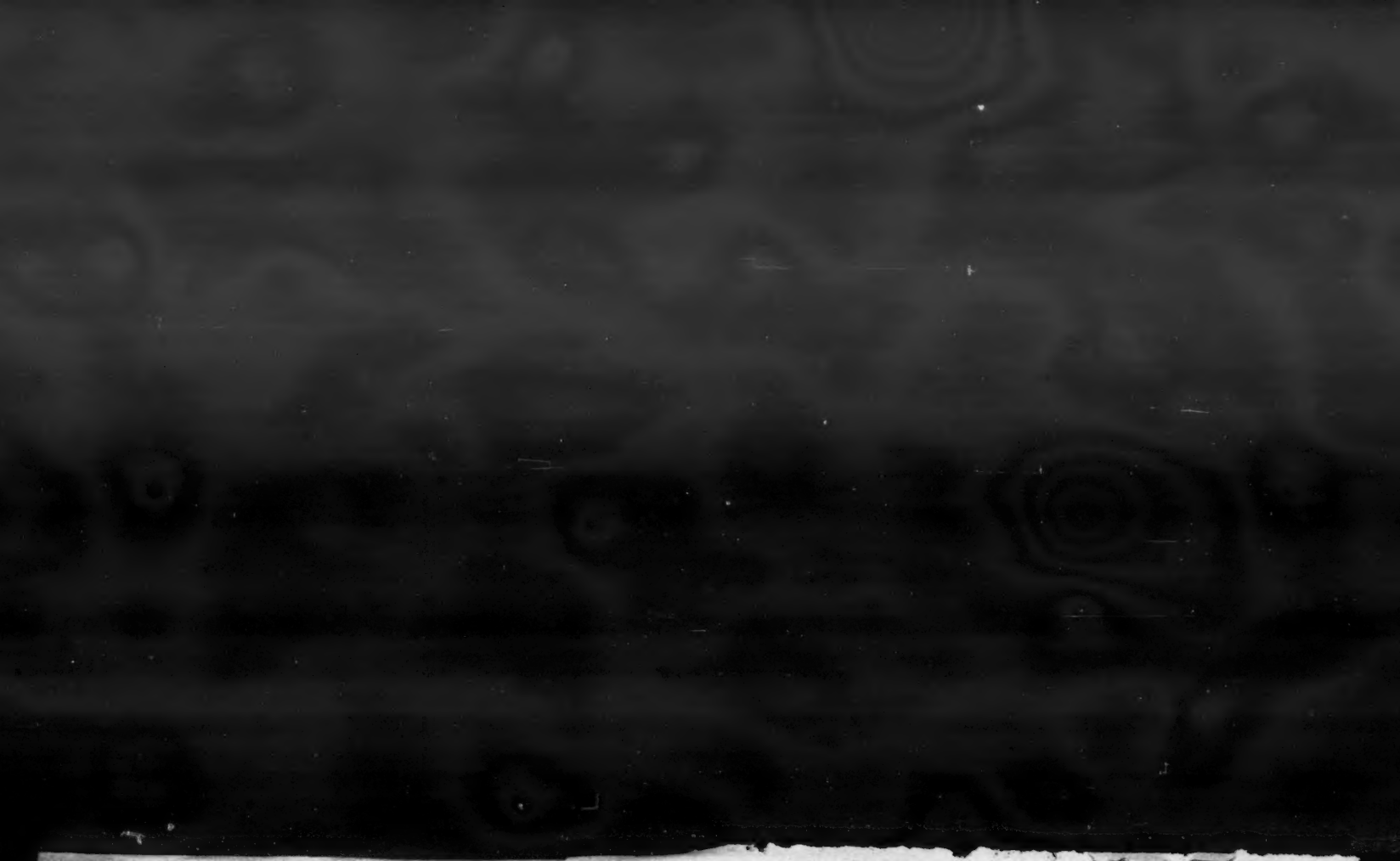
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